The nature of awe in science communication

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Abstract

Awe appears often in the communication of science. This emotion is commonly described as a universal and innate emotion resulting from evaluating an object as vast and forcing a change in people's worldviews. In its association with curiosity and learning, this emotion has been portrayed as a potential tool for science communicators to engage with their audiences. This narrow description mostly ignores, however, the many layers of sociocultural reality within which an emotion is bound. I approach awe in science communication using a constructionist view of emotions, a theoretical framework that accounts for the historical and cultural specificity of emotions within biological constraints, their enculturation and acculturation processes, and their multiple representational varieties. Throughout this thesis, I present evidence indicating that awe is valued in the culture of science communication, that people who engage with this culture are more skilled at conceptualizing awe, and that there are multiple types of awe in this space, each being privy to the historical and sociocultural realities where this emotion is represented.

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Preface

The main ideas in this thesis are based on my own original research. Some of this research has been presented at international conferences and seminars. This includes the presentations “Is science awesome: Reframing the use of awe in science communication” presented at the *Public Communication of Science and Technology Conference 2020+1*, “Cultural varieties of awe: The case of science communication” presented at the *Resilience and Awe 2021 Symposium*, and “Varieties of awe in science communication” presented at the *Science Public Engagement partnership conference 2021*. More important, elements of chapters 2, 3, and 4 have been included in the paper *The construction of awe in science communication*, published in the journal *Public Understanding of Science*, and which I co-authored with my primary supervisor Dr Jesse Bering. Versions of various paragraphs and sentences in this thesis appeared in this published article. These sections are referenced in the footnotes.

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Chapter one - Introduction

How can a concept like 'Awe' have such diversity: awe of the vastness of the universe; awe of Erik Weihenmayer, who scaled Mount Everest while blind; and awe that a tiny worker ant can carry five thousand times its body weight? The classical view proposes that you are born with these concepts, or that your brain finds emotion fingerprints in people's expressions and internalizes them as concepts. But we know that scientists haven't found such fingerprints, and infants show no evidence of being born knowing 'Awe.'

– *Lisa Feldman Barrett*, How emotions are made (2017a, p. 94)

It was in my first month after starting my research project when I realized I had to scrap my original proposal and go back to the drawing board. I had picked up Lisa Feldman Barrett's book *How Emotions Are Made: The Secret Life of the Brain* (2017a) at a bookstand at the airport in Doha and had begun reading it on that long flight to Auckland. The book's claims about the cultural contingency of emotion and varieties of emotional experience were in direct contradiction with all I had previously learned about emotion and the research proposal I had submitted for my PhD. In that proposal, I had claimed that 'awe' could be used to get anyone interested in science, yet what Barrett articulated in her book suggested that people across cultures experienced emotions differently; 'awe' was not necessarily going to appeal to everyone.

This revelation, however, seamlessly matched with my own intuitions and experiences with emotion across cultures. Having lived in three countries and speaking their distinct languages, I had long struggled with the 'problem of translation' of emotion words (Lutz, 1988, p. 8). I found that words such as '*amor*' and '*querer*' used to express different forms of affection in my native Colombian Spanish, didn't correspond to words such as '*aşk*' or '*sevmek*' in Turkish and 'love' or 'liking' in English, which were used in similar yet different circumstances. Being unaware of the many cultural nuances that characterized the appropriateness of each of these terms in context had resulted in many awkward situations, which were often accompanied by feelings of confusion, rejection, and even guilt. Those types of experiences had always left me with a nagging sense of the difficulty of conveying meanings across cultural contexts, and amazement over the variety of ways in which people experience and express their emotions.

It turns out, if one subscribes to Barrett's arguments in her book, that it is quite common for immigrants such as myself to feel a mismatch between our emotions and those of the places we move to (Barrett, 2017a; see also De Leersnyder et al., 2011). Instead of being a straightforward problem of mistranslation or misreading social cues, it is, instead, an issue of lacking the conceptual knowledge to construct experiences in line with the cultural-specific meanings of our new environments. That is, it is primarily a problem of not knowing the corresponding emotions of our adopted cultures.

My original PhD project proposal assumed, wrongly, as I will argue, that everybody experienced awe the same way that I do. Exposed to images from the Hubble telescope or descriptions of the ingenuity that took humans to the moon, I expected people would be overcome with a wonderous delight that would challenge whatever mental pre-conceptions they had, becoming curious about the scientific topic of the day, and ultimately becoming enamoured with science; awe as a sort of gateway drug to science. Consequently, my initial proposal was all about instrumentalizing this emotion to increase people's engagement with science communication.

After all, that had been my own experience with awe and science growing up. Or at least, it was the story I had told myself. I considered myself to be the poster child of how encounters with awe from consuming science communication in one's youth can spark a life-long passion for science. Growing up, nobody in my family or extended circle was a scientist nor cared much about it. We lived a comfortable middle-class lifestyle in a society where access to science was not common. However, science communication punctuated our little cocoon when science-related occurrences shook our routines and momentarily captured our attention. It was like that in 1986, for example, when Halley's comet returned to Earth's proximity after seven decades of meandering around the solar system. This news event gave my parents the astronomy bug, from which they bought a small telescope, took me to the local planetarium, and sat me with them to watch reruns of the series *Cosmos* on public television. It was this last thing which gave me the strongest impression. Although I was too young to understand much of the science described by Sagan, the visuals were like nothing I had seen before. The strong affective experience imprinted upon me by the show led to a fascination for science that I was never truly able to shake off. Even after being sent to a school that had little interest in producing scientists and growing up surrounded by people who couldn't care less about such matters, I still carried a deep interest in science. Whether reading a science article in the newspaper or watching some documentary on the Discovery Channel, science quickly became an essential part of my life. Years later, after having stumbled upon the scientific literature on the study of awe (e.g., Keltner & Haidt, 2003; Valdesolo et al., 2016), I would remember the emotions I had experienced as a four-year-old glued to Carl Sagan on the TV. I assumed that my love for science, one that in fact led me to pursue a PhD in science communication, had been the result of those early encounters with awe. My belief in the transformative power of this emotion, and somehow harnessing it to get more people into science, was the theme of my initial research proposal to the Centre for Science Communication at the University of Otago.

So, when I read Barrett's views on the constructed origins of emotions, this was a stumbling block for me, but it was a critically important turning point in my thinking. The book had given me grave apprehensions about my original PhD proposal, and you can perhaps picture the depth of the crisis I was thrown in just as I arrived in Dunedin. I realized that emotions are much more nuanced and complex phenomena than the "classical" view tended to present them as, and I was drawn back to the drawing board, trying to grapple with the implications of what Barrett's constructionist view of emotions meant for the study of awe in science communication. To dissociate myself from much of what has been written about awe and its role in science communication, I went back to square one. The present thesis is therefore the result of my attempts to come to terms with Barrett's novel insights and reflects my efforts to apply these to understand the nature of awe in science communication.

The constructionist view of emotions revolutionized my understanding of emotions and science communication, and in fact, it changed my understanding of the human experience. It opened me up to the idea that discrete emotions result from deeper layers of domain-general processes and assume various forms and functions, which are situated in sociocultural contexts. This broadened the space of investigation from the individual to include the broader cultural and historical contexts in which people moved. This also gave me the opportunity for combining quantitative and qualitative methodologies through which to study emotions in culture. Moreover, it helped me reconceptualize science communication not as an activity of transmission of information, but rather as a cultural space: a set of meanings shared by groups of people and represented in a wide range of products and practices. More importantly, I came to see science communication as a multiplicity of spaces, each of which has different sets of meanings due to the contrasting and sometimes contradictory sets of values, beliefs, norms, goals, and worldviews present in these spaces. In this thesis, I have tried then to articulate these larger frameworks of meaning to the various ways in which awe gets represented in science communication. I hope that my enthusiasm and intellectual "conversion" to the constructionist view of emotions has percolated into the writing, as I believe it has revolutionary implications for how we talk about and practice science communication.

The ensuing chapters represent my journey through the worlds of emotion research, trying especially to ascertain how awe has been regarded and conceptualised in science communication. The second chapter presents a literature review of some of the main topics discussed in the rest of the work (i.e., emotions, awe, knowledge, science communication, and emotions in science communication). Here I argue that the literature on awe and that of emotions in science communication is inadequate to the task of capturing the culturally specific varieties of awe in this space as it has been for the most part conceptualized within the classical view of emotions. The third chapter introduces my distillation of the analytical and theoretical framework that permeates the studies in the following chapters. In this chapter, I present the situated conceptualization framework for studying emotion categories, describe my take of the constructionist view of emotions, and conceptualize science communication as a cultural space. Having defined awe as a culturally and historically contingent emotional category chapter four heeds the call made by Daniel Gross and Stephany Preston to "always historicize" (2020, p. 9) emotion research. Consequently, this chapter outlines a brief history of the emotion category awe, its early social meanings as a religious emotion, its jump to popular expressions of science in the late 18th and early 19th century, and the evolution of its themes in science communication until today. Importantly, this chapter suggests that awe has historically been a valued emotion in this cultural space, a hypothesis I set out to test in the fifth chapter. This chapter reports a study which describes differences in the frequency and centrality of social representations of awe in science and non-science picture books. Finding some evidence of how the culture of science communication values this emotion in the analysis of picture books, the sixth chapter sets out to compare people's mental representation of this emotion in relation to their level of engagement with this cultural space using a word association paradigm. After arguing that emotions are learned in the socialization practices and interaction with cultural products in the contexts where people spend their time, I attribute the observed differences in people's representation of awe to differences in their level of skill resultant from their engagement with science communication. Then, I present the results of my analysis of interviews about awe with science communicators. Here, I identify a variety of awe types in science communication around particular themes. These themes, I argue, correspond to the different cultural mandates (i.e., values, beliefs, goals, norms) that are co-constructed in the various science communication spaces. Finally, I conclude with a summary chapter that includes a brief discussion of the results, a broader examination of the implications of the constructionist view of emotions in science communication, and potential future directions. Together, the review, framework, studies, and discussion presented here contribute to the overall debate of the role of emotions in science communication and the nature of awe more broadly.

Chapter two - Literature review

2. Introduction

Throughout this thesis I draw upon knowledge from many disciplines in social science and the humanities, including psychology, science education, anthropology, communication studies, sociology, philosophy, history, and theology, to study the nature of awe in science communication. This interdisciplinarity, I believe, fits well within the current debate over the nature of science communication as a discipline (Gascoigne et al., 2010; Trench & Bucchi, 2010), which corresponds to a larger dialogue within social science about the need for syncretic and holistic cross-collaborations (Nissani, 1997).

In this chapter, I present an overall review of five different literatures that look at the topics of emotion, awe, mental representation, science communication, and the study of emotions in science communication. First, I briefly review the literature on the nature of emotions and, in particular, the literature that asks, 'what is awe'. Because most of this work has been done from the classical view of emotions, I do a brief overview of this paradigm before delving into the developments in the study of this emotion of the last two decades. I conclude this section by briefly introducing a competing paradigm in the study of emotion – the constructionist view. The nature and ramifications of this novel paradigm will be elucidated in the theoretical and analytical framework (chapter three). Following this, I turn my attention to the literature on knowledge and representation, centring on four debates on the topic. Focusing on theories of mental representation, I discuss whether knowledge is grounded or not (modal vs amodal), the role of language, the meaning of meaning for these theories, and the topic of abstract concepts. This discussion precedes the situated conceptualization framework developed in the next chapter. In the third section, I review the dominant theoretical framing of science communication around three models (deficit, dialogue, participation). In this section, I argue that these not only describe forms of transmitting information but also serve to describe the various contrasting and competing cultural mandates within science communication. I conclude with a brief review of the literature of the study of emotions in science communication. I argue that most work on emotions in science communication has failed to take into account the latest developments in the science of emotion, sticking to the very narrow definition of emotions provided by the classical view.

Due to the broadness and ambitiousness of the project and topics in this chapter, I will not be delving into the minutiae of every discussion. This is the case for the discussions on theories of emotions, theories of knowledge, and theories of science communication, where multiple in-depth reviews already exist that tell the history, describe the important concepts, and highlight the current debates in each of these fields. Hence for these topics, I try to focus on some of the landmark studies and cite the most significant reviews where the reader can delve further into these discussions. Moreover, this chapter does not present the framework I use throughout the rest of this PhD thesis. The theoretical and analytical framework of this thesis is presented in chapter three, while the methodological framework for each of the studies is presented in their corresponding chapter (i.e., chapters four through eight).

2.1. Emotion research in affective science

There is profound disagreement among specialists in the field of affective science when it comes to a stand-alone definition of emotion. The core disagreement is in the way that the different theories conceptualize the ontological status of the category 'emotion'. Barrett (2012, 2016, 2017b) describes two camps separated for the most part around one dimension: *essentialism*. Essentialism in emotion is defined as "the belief that a category of instances named by the same word (such as 'anger', 'pride', 'awe', etc.) or a phrase (e.g., 'basic emotion theories', 'appraisal theories', etc.) share a deep, underlying causal mechanism" (2016, p. 33) and a "fingerprint" or "prototype" (2016, p. 34). Barrett (2006a, 2016, 2017b) argues that the urge to essentialize has been present in the science of emotion from its early discussions and that models which essentialize the nature of emotions stand in stark contrast to the models that do not. This division divides the field into two camps, those who follow a classical view of emotions (i.e., essentialist), and those who argue that emotions are constructions (i.e., non-essentialist) (Barrett, 2016, 2017a, 2017b; see also Averill, 2012). Based on these opposing views of emotion, investigators from each camp ask different questions, use different definitions and assumptions, and have distinct research agendas in which they rely upon divergent analytical tools and procedures. For most of the 20th century, most emotion researchers favoured the classical view (Gendron & Barrett, 2009). However, over the first decades of the 21st century, there has been an ongoing shift towards the constructionist view. Barrett (2017c) has referred to this shift as a 'scientific revolution' and a 'paradigm shift' in the study of emotions. In the next sections, I briefly review both the essentialist (i.e., the classical view of emotions) and non-essentialist (i.e., the constructionist view of emotion).

2.1.1. The classical view of emotion

The models and theories in the classical view treat emotions as discrete faculties made from independent and distinct processes (Barrett, 2016). Emotions are described as separate from other cognitive and perceptual processes (e.g., memory, attention) and cannot be ontologically reduced to more basic mechanisms (i.e., psychologically primitive) (see Tracy & Randles, 2011), making emotion research its particular research niche. The differences among emotions are the result of physical and/or psychological mechanisms that are different for each emotion (e.g., a fear mechanism, an awe mechanism, etc.) and instrumental to the emotional episode. Moreover, the classical view of emotions conceives every instance of emotion as having a particular 'fingerprint' – a set of physical and psychological manifestations that repeats itself on every occasion – and these can be identified through objective measures such as facial expressions (e.g., Cordaro et al., 2018; Ekman & Friesen, 1971), responses of the autonomic nervous system (e.g. Ekman et al., 1983; Shiota et al., 2011), patterns of distinct appraisals (e.g. Lazarus, 1991), and/or distinct brain activation configurations (e.g. Vytal & Hamann, 2010). The causal mechanisms and the 'fingerprints' are usually treated as biologically pre-wired, which means that most authors identify these underlying aspects as being present across cultures (e.g., Cordaro et al., 2018; Ekman, 1992) and contiguous across species (e.g., Panksepp, 1998). According to Barrett (2016), there are two variants of the classical view of emotions: basic emotion[1] and causal appraisal models[2]. Each of these variants has dozens of different exponents that disagree about the minutiae of

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[1] Basic emotion models view emotions such as anger and fear as discrete mental events triggered by a stimulus and expressed by facial displays (Ekman & Friesen, 1971), neural (Ekman et al., 1983), motivational (e.g., Frijda et al., 1989), and phenomenological outputs (e.g., Matsumoto et al., 2007), and coordinated by a specialized mechanism (e.g., affect programs) (Tomkins, 1962). Most basic emotion models credit the adaptive interaction between behaviour and environment as selecting for the basic emotions. According to their framework, these outputs facilitated a set of behaviours that enabled individual members of the species to solve recurring problems in the environments of evolutionary adaptedness (Ekman, 1992; Ekman & Cordaro, 2011; Keltner et al., 2006; Tracy & Randles, 2011).

[2] Causal appraisal models (Frijda, 1986; Lazarus, 1991; for a review, see Moors et al., 2013) share various characteristics with basic emotions models, situating them in the classical view of emotions. The term 'appraisal', coined by Arnold (1960), is used to refer to a cognitive mechanism of evaluation of the environment for the satisfaction of the individual's concerns (i.e., interests, goals, values, beliefs) (Moors et al., 2013). For these theories, appraisals function as causal mechanisms that regulate which stimuli create an emotion, which emotion is elicited, and the intensity of the elicited emotion (see Moors, 2010a). Causal appraisal models argue that once a stimulus is evaluated through an appraisal mechanism, it triggers a series of other components, which can be motivational (i.e., action tendencies, action readiness) (e.g., Frijda, 1986), somatic (i.e., peripheral nervous system responses) (e.g., C.A. Smith, 1989), motor (i.e., behaviour, expressions) (e.g., Scherer, 1992) and phenomenological (i.e., feelings) (Moors, 2010b). These components have a specific 'fingerprint' that an external observer can objectively measure. Therefore, the emotion episode is the summation of everything that happens between the stimulus and the end of the interaction between the different components. This conceptualization of appraisals as causal mechanisms and the different components as having specific 'fingerprints' characterizing between and among emotions, makes causal appraisal theories part of the classical view of emotions (Barrett, 2016).

the categories and mechanisms of emotion but for the most part converge around a set of principles, definitions, and a common research agenda.

This is particularly true of their description of culture as secondary to biological imperatives. The basic emotions view argues that emotions such as anger, fear, and sadness evolved independently to deal with ancestral problems, such as restoring relations (e.g., Keltner et al., 2006), coping with a threat (e.g., Tracy, 2014), and soliciting help when facing harm (e.g., C. A. Smith & Lazarus, 1990). As a result of this evolutionary heritage, such affective programs are seen to be universal and hardwired among humans. For most researchers who adopt this basic emotion perspective, culture moulds people's regulation mechanism, such as display rules (Ekman et al., 1969; Ekman & Cordaro, 2011), emotional suppression (J. J. Gross & Levenson, 1993), or cognitive styles (Engelmann & Pogosyan, 2013), which mask, restrain, and augment people's emotions, combining these to create more sophisticated and diverse emotional experiences (Plutchik, 1991). As part of this conceptualization, basic emotion theories do not view culture as constitutive, but rather as supportive of an emotion episode (for a review, see Tracy & Randles, 2011). Likewise, many causal appraisal models take some basic core group of appraisals such as novelty, intrinsic pleasantness, and fairness as present in all humans (e.g., Scherer, 1997). Some of these models also assume that specific combinations of these appraisals always lead to the same emotional experience. For example, a novel situation in which an agent can be made accountable and obstructs a person's goals should lead to an experience of anger (e.g., Ellsworth & Scherer, 2003; Lazarus, 1991). This should happen regardless of the person's cultural background; the same appraisal pattern in any situation should always trigger the same emotional episode. The universality of this appraisal-to-emotion correspondence has been termed the hypothesis of universal contingencies (e.g., Ellsworth, 1994; Mesquita & Ellsworth, 2001; Scherer, 1997). In this scenario, culture only explains the differences in the relation between the stimulus and how it is appraised.

Recent iterations of some of the classical view models have given a more significant role to culture in the emotional episode, both in the basic emotions (e.g., Keltner et al., 2019) as in causal appraisal models (e.g., Scherer & Fontaine, 2019). In their view, culture regulates the relationship between the stimulus and the emotion, impacting the interaction between the components constituting the emotional episode, and thus explaining the emotional variability observed in the empirical studies. However, the attention paid to culture still casts it in a subordinate position, as a mostly tangential component of the emotional experience. Overall, the classical view does not see culture as constitutive but rather as regulating an emotion episode.

2.1.2. Awe in the classical view of emotions[3]

Throughout the 20th century, most of the scant literature describing awe in affective science dealt with these states as discrete and composite events constituted from a series of primary or basic emotions. Early emotion authors such as Stanley Hall (1897), Floyd H. Allport (1924), and William McDougall (1908/2015) saw states such as awe, wonder, surprise, reverence, and sublimity either as refined and complex forms of fear or as secondary and tertiary emotions resulting from amalgamating more basic ones. In a similar vein, Lazarus (1991) refers to awe as a mixture of amazement and fright. By contrast, Ekman (1992), who saw awe as a complex emotion, for the most part, toyed with the idea that perhaps one day it could be upgraded to basic emotion status[4]. While most of these theories of emotion dedicated a few lines to awe, most references were made in passing, as the bulk of these researchers' attention was devoted to 'basic' emotions such as fear and anger.

A theoretical breakthrough in awe research occurred when Keltner and Haidt (2003)[5] authored a landmark review article on awe, drawing from various traditions to define and operationalize this emotion. The authors used a prototype approach (Fehr & Russell, 1984) to do a hermeneutic distilment of the core themes of awe in the different conceptualizations of

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[3] Related emotion categories such as wonder and elevation have been referred to as belonging to the awe family of emotions (Shiota et al., 2007) or as awe-like emotions (Silvia et al., 2015). Although there have been many attempts to define and empirically examine such other emotions (e.g., Darbor et al., 2016; Shiota et al., 2014; Valdesolo et al., 2017) these are few and far between. This next section will be then devoted primarily to the literature from the affective sciences focusing on the category 'awe'. However, I will come back to other literatures exploring emotion categories such as wonder and the sublime which I will treat throughout this thesis as analogous to awe.

[4] In later iterations of his model, Ekman corrected that he was referring to 'wonder' in his work when using the word 'awe' (Ekman, 2003). Moreover, he continued to argue that 'wonder' could be promoted to basic emotion (Ekman & Cordaro, 2011).

[5] Researchers such as Dacher Keltner and Michelle Shiota are currently the heirs to the classical view of emotions. While defending many of the ideas presented by Ekman, Frijda, and Levenson, these scholars have turned their attention to the so-called positive emotion categories such as pride, gratitude, amusement, and love, after these were somewhat neglected by the previous generation of affective scientists (Keltner et al., 2019; Shiota et al., 2017). In a recent review, Shiota et al. (2017, p. 633) write: "We anticipate that data will ultimately point to a convergence of the discrete function, appraisal component, and dimensional theories of emotion, in which each understanding of 'emotion' maps to a psychological mechanism that is real in the neural, behavioural, and phenomenological sense." This call to find 'real' 'psychological mechanisms' in the 'neural, behavioural, and phenomenological sense' that 'map' to 'each' emotion, parallels claims about the 'fingerprints' of emotions such as affect programs and/or appraisals as causal mechanisms, throughout the 20th century. The research program proposed by Shiota et al. (2017) continues to focus on describing emotions as discrete, universal, and primitive, aiming at defining the core components (i.e., appraisals, expressive behaviour, physiological responses, neural mechanisms, motivational characteristics) that characterize each emotion, and observing the consequences of emotional episodes on things such as cognition, behaviour, and well-being. Despite much debate about the nature of emotions, these authors and their peers continue to produce an ever-increasing body of work to support their views of emotions based on the classical view.

the subject, using works from religious studies, sociology, philosophy, and psychology. After pointing out the commonalities and core themes in these different theoretical treatments, the authors defined awe as the result of two central appraisals, *vastness* and a *need for accommodation*. By vastness, the authors meant evaluating a perceptually, or metaphorically, information-rich stimulus, one that is experienced as larger than the self. The need for accommodation refers to an adjustment process of the new information being "accommodated" into a new or expanded mental structure. Keltner and Haidt (2003) also distinguished five other appraisals that give nuance to the awe experience. These other appraisals include the perception of threat, beauty, ability, virtue, or supernatural causality in the stimulus, which give the emotion a different valence and vary the 'flavour' of the emotional episode. Finally, the authors present an account of awe whereby the emotion is defined as an adaptive response to specific environmental situations. For the particular social circumstances in which humans evolved, 'primordial' awe served as a way of regulating relations between lower and higher status individuals, reinforcing social hierarchies. This primordial awe response is presumed to be present in contemporary environments where the implicit cues for social dominance now spill over to other stimuli associated with power and enormity, such as natural disasters, celebrity sightings, large vistas, and grand theories.

Keltner and Haidt's (2003) definition of awe fits squarely within the classical view of emotions. Appraising a stimulus as vast and in need of accommodation is conceptualized by the authors as sufficient and necessary conditions for the ensuing affective episode to be considered 'awesome'. While most prototype approaches define emotion categories as having no sharp boundaries that separate experiences from non-experiences (Russell, 1991b), the authors carve out a unique space to discriminate between members and non-members of the emotional category, giving it the discreteness that emotions in the classical view have. This definition is based on Aristotelian essentialism, whereby the boundaries of what is and what is not, is at the core of its description (Gelman & Rhodes, 2012). Interestingly, while prototype studies tend to form conceptualizations of emotion from empirical research to first understand the folk usage of emotion words in people's day-to-day lives (e.g., Fehr & Russell, 1991), Keltner and Haidt derive their definition from academic discussions in different fields of knowledge.

This conceptualization of awe discards the inherent variability of the concept in actual usage, favouring a prescriptive stance that in psychology tends to fall inadvertently into essentialism (e.g., Palmer, 2002). Their definition of appraisals as triggers of the emotional experience is well within the appraisal theories that treat these antecedents as causal mechanisms required for the emotion episode to occur. This form of Lockean essentialism – every emotion having an underlying causal mechanism – is also the hallmark of the classical view (Barrett, 2016). Finally, the idea of 'primordial' awe, whereby this emotion is envisaged as having evolved alongside others to cope with a particular recurrent adaptive problem in our ancestors' social environment (see Keltner et al., 2006), is very much in line with basic emotions theories that treat particular emotions as the result of natural selection pressures, making it universal amongst our species. These essentialist and universalist characteristics of the definition of awe proposed by Keltner and Haidt (2003) incorporate both basic emotion and causal appraisal ideas to describe the sources, experience, and possible consequences of an emotional episode. Though Ekman (1992) insinuated the possibility that awe might be a 'basic emotion' a decade before Keltner and Haidt's (2003) account, the latter's conceptualization has defined the research agenda of this affective state since its publication. As a result, the vast majority of studies appearing since this time fit squarely within the confines of the classical view of emotions. The rest of this section highlights some of these studies that have looked at the different aspects of an awe episode.

2.1.3. The awe episode

Theoretical and empirical accounts of awe suggest that this emotion can be 'triggered' by all sorts of social, physical, or cognitive events, such as meeting powerful people (e.g., a famous actor, a talented sports star), looking at a grand vista (e.g., the Grand Canyon, Earth from space), or contemplating a grand theory (e.g., Darwin's theory of evolution, Einstein's theory of general relativity) (Keltner & Haidt, 2003). A few experiments have used slideshows with static images of panoramic views of nature (Shiota et al., 2011) or deep space (Silvia et al., 2015) to 'cause' this emotion. More common is the use of videos of natural settings such as panoramic views of waterfalls, oceans, and deserts (e.g., Prade & Saroglou, 2016; Saroglou et al., 2008; Van Cappellen & Saroglou, 2012), sometimes taken from the BBC *Planet Earth* series (e.g., Bai et al., 2017; van Elk et al., 2016; Piff et al., 2015). Other studies used videos that compare the sizes and distances in the universe (e.g., A. M. Gordon et al., 2017; Stellar et al., 2018), slow-motion captures of coloured water (Piff et al., 2015), and recordings of a couple's days before and after having a child (Saroglou et al., 2008; Van Cappellen & Saroglou, 2012). In some cases, participants are asked to read short stories such as going to Paris and standing atop the Eiffel Tower (Griskevicius et al., 2010; Rudd et al., 2012), or one-liners that capture a powerful experience in nature (Cordaro et al., 2018). In vivo inductions of awe have also been employed; for example, participants have been asked to look at a *Tyrannosaurus Rex* replica (Shiota et al., 2007), stand amongst tall Tasmanian Eucalyptus trees (Piff et al., 2015), stare from the top of a bell tower (Stellar et al., 2018), visit Yosemite National Park (Bai et al., 2017), or go white water rafting (Anderson et al., 2018). All of these studies point toward the variety of agents, objects, and settings, whereby people describe experiencing this emotion.

When it comes to the evaluations that occur during an awe episode, data have suggested that Keltner and Haidt's (2003) conceptualization that vastness and challenges to one's worldview (i.e., need for accommodation) indeed occur during awe episodes (Shiota et al., 2007; Yaden et al., 2019). Moreover, studies have also observed the five extra appraisals – beauty, threat, exceptional ability, virtue, and supernatural causality – proposed by these authors to complement the initial two appraisals (e.g., A. M. Gordon et al., 2017; Yaden et al., 2019). Other authors have proposed that additional appraisals, such as attributing agency of the events surrounding the episode to others and sensing that the events are beyond anyone's control, could complement Keltner and Haidt's original appraisals (Tong & Jia, 2017). While there is some consistency across studies around the stereotypical appraisals, there are also reports that describe various idiosyncratic ways in which participants evaluate awe-inspiring situations (e.g., Dobson, 2015).

Studies looking for similarities in the production and recognition of expressions during awe episodes have focused on facial, vocal, and body displays. Using the Facial Action Coding System (FACS) introduced by Ekman and Friesen (1976), a study observed that participants who were asked to display awe non-verbally frequently raised their inner eyebrow, widened their eyes, displayed an open drop-jawed mouth, sometimes tilted their head forward, and produced visible inhalations (Shiota et al., 2003). Another study that analysed images of 230 participants using FACS found consistent results for facial expressions of awe (Du et al., 2014). However, this study also described how facial displays of awe could be confused with conceptualised expressions close to fear and surprise. Studies in this area have also examined vocalisations associated with awe. Simon-Thomas et al. (2009), for example, observed that participants could recognise vocal displays for awe at above-chance levels. Similarly, the 'wow' vocal burst that is stereotypically used to express awe was strongly recognised as "the awe vocalisation" across cultures (Cordaro et al., 2016). However, such studies have been criticised for using methodological practices such as forced-choice, which raise questions about their validity and generalizability (see Barrett et al., 2019).

Further studies have looked at the affective component of awe experiences. Studies that have examined the basic affective attributes of valence and arousal, associated with the somatic component and captured in the concept of core affect (Russell & Barrett, 1999) produced conflicting results. Arousal, measured in autonomic nervous system changes, has shown contradictory patterns of activity in the different studies (e.g., Chirico et al., 2017; A. M. Gordon et al., 2017; Maruskin et al., 2012; Schurtz et al., 2012; Shiota et al., 2011), suggesting that the emotion may come with feelings of both excitement and calm. With both sympathetic activation and withdrawal being reported in the literature as accompanying awe, such mixed results led one group of authors to describe awe as having a "novel and complex autonomic profile" (Shiota et al., 2014, p. 365). Furthermore, while the initial results described awe as a positively valenced emotion (Shiota et al., 2007), one recent study has put that assumption into question with at least one-fifth of participants describing the experience as negative (A. M. Gordon et al., 2017). This affective ambivalence is also reflected in some of the qualitative studies (e.g., Dobson, 2015).

People also report a variety of phenomenological themes related to the meanings ascribed to the awe episode. Perhaps the most important recurring theme appearing in reports of awe-like experiences is the so-called *small-self effect*. In general, this effect refers to a diminishment of a person's sense of self (Piff et al., 2015). Several quantitative (e.g., Campos et al., 2013; van Elk et al., 2016) and qualitative studies (e.g., Bonner & Friedman, 2011; Dobson, 2015) have corroborated this theme. In addition to the small self, other themes appear in the awe literature, although most of these have yet to be adequately defined and/or assessed. One such conceptualization of feeling is that of self-transcendence. Self-transcendence has been identified with a feeling of going beyond mundane concerns and desires and is associated with a decrease in the salience of the self and a feeling of connectedness (Shiota et al., 2014; Yaden et al., 2017). A feeling of being in-the-moment has also been reported in both quantitative (e.g., Rudd et al., 2012) and qualitative studies; it has been described as akin to a feeling of presence (Bonner & Friedman, 2011) or detached observation (Dobson, 2015). Likewise, feelings of uncertainty are also regularly observed in the awe literature (Dobson, 2015; Valdesolo & Graham, 2014). Other themes have included subjective feelings of not wanting the experience to end (Shiota et al., 2007), overwhelmingness (Dobson, 2015; Gallagher et al., 2015), and profoundness (Bonner & Friedman, 2011; Silvia et al., 2015). Again, however, such themes, have not been thoroughly explored, and in many cases have been lumped together with definitions of vastness and need for accommodation (e.g., A. M. Gordon et al., 2017; Piff et al., 2015; Shiota et al., 2007).

Behavioural and motivational drives have also been conceptualised for awe. Over a century ago, McDougall (1908/2015) argued that wonder accompanies the curiosity instinct. More recently, researchers have argued that awe motivates exploration and causal explanation, in that the emotion is evoked by the violation of expectations and the need for accommodation that ensues (Valdesolo et al., 2017). Valdesolo & Graham (2014) found that awe decreases people's tolerance for uncertainty, motivating them to seek answers. Valdesolo et al. (2016) also found that awe drives non-theists towards scientific descriptions that provide an explanatory framework. This motivational drive was argued to be the source of increased play in children in an awe condition (Colantonio & Bonawitz, 2018). This explanatory drive has also been found in some of the few qualitative studies done in this area. Dobson (2015) observed that some of her participants expressed an urge to seek patterns and meanings in their awe experiences, while Gallagher et al. (2015) reported that seven astronaut reports and 22 interviews conducted after space simulations contained instances of inquisitiveness. These findings contrast with those of a study by Joye and Dewitte (2016), which suggested that awe led to behavioural freezing rather than exploratory activity. These latter data would seem to challenge the argument that awe can be instrumentalised in some straightforward way that motivates people to explore and learn (e.g., Valdesolo et al., 2017).

Many studies have also examined changes in cognition, perception, behaviour, beliefs, and wellbeing in the wake of an awe experience. Griskevicius et al. (2010), for instance, observed that individuals who experienced awe displayed a more systematized scrutiny of the message and were less convinced by the weak argument. Similarly, Danvers and Shiota (2017) found that, when asked to recall the details of a narrative, participants in a state of awe depended less on their internal knowledge of how things 'should be' (i.e., accepting fewer false details that were consistent with the traditional 'dinner script') than were control participants. Chirico et al. (2018) reported how, after experiencing awe in virtual reality, participants' creative thinking increased, in that they exhibited greater fluidity, flexibility, and elaboration. Rudd et al. (2012) also reported that participants in the awe condition felt less impatience and more willing to help other people by volunteering and favouring experiences over material goods (e.g., a movie theatre pass vs a jacket). Similarly, Van Cappellen and Saroglou (2012) found differences in behavioural intentions: participants who experienced awe chose a spiritual over a hedonistic travel destination (e.g., Tibet vs Haiti). Saroglou et al. (2008), reported that participants described higher levels of spirituality after being exposed to awe-eliciting videos. Similar results were found by Valdesolo and Graham (2014), who observed that, compared to controls, people exposed to awe stimuli scored higher on various measures of supernatural beliefs. Other changes that have been attributed to awe include pro-social behaviours (Piff et al., 2015), humility (Stellar et al., 2018), increases in personal growth goals (Seaton & Beaumont, 2015), decreased desire for money (Jiang et al., 2018), less aggressive impulses (Yang et al., 2016), improvements in life satisfaction (Rudd et al., 2012), and increases in wellbeing (Anderson et al., 2018). Such studies indicate an assortment of outcomes from an experience of awe in both daily life and under laboratory conditions.

Less, however, has been written about the cultural sources of awe as, for the most part, studies have been aimed at showing the universality of this emotion across cultures. Cordaro et al. (2016, 2018), for example, reported universal aspects of awe through vocal and facial expressions across cultures. Similarly, Razavi et al. (2016), Bai et al. (2017), and Nakayama et al. (2020) also reported its universality. However, these other studies also described differences across cultures. Razavi et al. (2016) found that U.S. participants reported significantly more day-to-day awe episodes than their Iranian counterparts. They attributed these findings to differences in extraversion between the two countries. Another study reported a few differences in the external objects present during awe episodes and in the magnitude of the small-self effect between Chinese and American participants (Bai et al., 2017), which they ascribed to the individualist/collectivist construct in social psychology (e.g., Hui, 1988). Finally, a recent study by Nakayama et al. (2020) reported differences in the valence of dispositional awe in a sample comprised of North Americans and Japanese participants, with the former being more prone to its positive version. Although these few studies have observed differences in the conceptualization of this emotion across cultures, these differences are mostly seen as cosmetic and described as epiphenomenal to the classical view's universalist claims.

The studies reviewed here are only some of the many studies on awe published since Keltner and Haidt's (2003) landmark article. Despite this wide range of awe experiences, most of these articles remain rooted firmly within the classical view of emotions, which argues for a universal, discrete, and relatively narrow definition of this emotion. However, given the increasing evidence of the weaknesses of the classical view, alongside advancements in the field of affective science over the last decade more generally, there is reason to suspect that this theoretical grounding is flawed.

2.1.4. Beyond the classical view of emotions

Over the last thirty years, the classical view of emotions has been increasingly challenged, as many studies find little to no evidence of emotion essences. These studies are not only presenting data disconfirming the classical view but are also uncovering multiple methodological and analytical issues with many of the original studies claiming support for basic emotions or causal appraisal models (Barrett, 2006a; Barrett et al., 2019; Gendron et al., 2018; Russell, 1994). These include significant differences in findings from slight methodological changes (Russell, 1994), disparities in results from different research groups (Elfenbein & Ambady, 2002), and significant variability within and across studies (Barrett et al., 2019). More importantly, the results of meta-analyses and literature reviews from the science of emotion cast serious doubts on claims of emotion 'fingerprints' being universal and consistent across the species (e.g., Barrett, 2006a; Barrett et al., 2019; Cacioppo et al., 2000; LeDoux, 2012; Lindquist et al., 2012; Russell, 1994; Siegel et al., 2018).

Studies that treat awe as a discrete and universal emotion with a measurable, observer-independent essence should be seen with these problems in mind. Arguments that awe has clear and specific facial expressions (e.g., Shiota et al., 2003), appraisals (e.g., Shiota et al., 2007), vocalizations (e.g., Simon-Thomas et al., 2009), and patterns of peripheral nervous system activation (e.g., Shiota et al., 2011), and that the emotion is also recognized in every culture (e.g., Cordaro et al., 2016, 2018) and experienced universally (Razavi et al., 2016), are based on an ontological, methodological, and analytical framework (i.e., the classical view of emotions) that stands on very shaky ground. This larger body of evidence casts doubt on the existence of emotion 'essences', shows that emotional variability is not the exception but the norm, and finds little evidence of universality in emotions. Thus, it must be considered when researching every emotion, including discussions about the nature of awe[6].

However, taken together, these studies show a very large range of experiences that people describe as awe-some. Whether it is the many situations that 'elicit' this emotion (e.g., Yaden et al., 2019), its complicated affective tones (e.g., A. M. Gordon et al., 2017; Shiota et al., 2011), the variety of themes described as accompanying its episode (e.g., Bonner & Friedman, 2011; Dobson, 2015), or the many outcomes from its experience (e.g., Bai et al., 2017; Griskevicius et al., 2010), the observations in the literature suggest a much richer, complex, and nuanced reality for this emotion, beyond Keltner and Haidt's (2003) narrow conceptualization. The reviewed literature on awe is a useful starting point, taking it for what it is: descriptions of some of the dominant stereotypes of awe in the particular cultural contexts in which these studies took place. This is one of the many insights of the constructionist view of emotions, whose scope and breadth represent a paradigm shift to the study of emotions (Barrett, 2017c).

2.1.5. The constructionist view of emotion

The current models in the constructionist view draw inspiration from a much longer tradition in philosophy, psychology, history, anthropology, and sociology. Many of the intuitions of the constructionist view of emotions were already present in philosophers such as Kant, Hume, and Spinoza (Barrett, 2017a). However, it was the work of scholars such as William James, Wilhelm Wundt, Elizabeth Duffy, Harry Harlow, and Ross Stagner, (Gendron & Barrett, 2009), and the work of many anthropologists, historians, and sociologists who challenged universalist claims (e.g., Abu-Lughod, 1988; Averill, 1980; Boddice, 2018; Lutz, 1988), that inspired the many theories in this new wave of constructionist models.

Models for understanding emotions in the constructionist view can be catalogued in relation to the level of analysis and attention that they give to each of the different aspects of the

[6] Authors in the classical view have instead accommodated these inconsistencies to their models and explained them as the result of epiphenomena such as display rules (e.g., Ekman & Cordaro, 2011), emotional suppression (e.g., J. J. Gross & Levenson, 1993), or the weakness of the stimulus presented (e.g., Levenson, 2011). Nevertheless, other authors see these issues as inevitably refuting most of the classical view's ontological and theoretical claims (see Barrett et al., 2019).

construction process, with some focusing on understanding the supporting brain networks, others putting their attention on the different psychological and developmental processes involved, and others focusing on the cultural and social aspects of the emotional experience. Constructive appraisal models (e.g., Clore & Ortony, 2013) treat appraisals as descriptions of the psychological states that make one episode different from another. Social constructionist models of emotion (Averill 1980; 2012) argue that emotions are constructions resulting from a person's interaction with their social environment. Such scholars contend that emotions cannot be reduced to physiological or behavioural variables, but are rather contextual, reflecting the meanings embedded in the norms, values, and institutions of a particular cultural setting (e.g., Mesquita et al., 2017; Mesquita & Leu, 2007). Cultural constructionist models move beyond the social-relational to focus on the systems of meaning, such as discourses, through which people make sense of emotions (e.g., Lutz, 1988; Illouz, 2008). This approach raises questions about the political and social structures that support the practice, expression, and socialization of emotions (e.g., Harding & Pribram, 2002; Lutz & Abu-Lughod, 1990). Historical constructionist approaches put the onus on thick descriptions of the time and place where the emotion categories circulate (e.g., Scheer, 2012; Boddice, 2018). Meanwhile, neuroconstruction models highlight how the interaction of dynamic large-scale intrinsic brain networks could correspond to the emergence of emotions from *domain-general* processes (e.g., Barrett, 2017c; Barrett & Satpute, 2013; Barrett & Simmons, 2015; Chanes & Barrett, 2016; Lindquist et al., 2012). These are just a few of the many constructionist proposals out there; models that nurture each other through evidence and discussions, often providing insights, concepts, and methods through which to study emotions in context.

The specific theoretical framework that I will use throughout this thesis and developed in the next chapter is a mixture of different approaches. However, I will mostly focus on Lisa Feldman Barrett's *theory of constructed emotions*. Initially introduced in 2006 as a psychological model of emotions called the *conceptual act theory* (Barrett, 2006b), this theory has continually been updated by incorporating the latest insights from neuroscience, cognitive science, cultural psychology, philosophy of the mind, and the results from empirical studies (Barrett, 2012, 2013, 2017a, 2017c; Barrett et al., 2014; Gendron et al., 2018, 2020; Hoemann et al., 2019; Lindquist & Barrett, 2012). A fundamental element of the theory of constructed emotions is that it defines the content of an emotion as a mental representation in the form of a conceptualization from previously learned emotion knowledge (Barrett, 2006b). This account of how emotions work relies on a specific kind of theory of knowledge and representation. Mainly, it takes a grounded cognition view of knowledge and borrows from the situated conceptualization framework developed by Lawrence Barsalou (Barsalou, 2003, 2009, 2016a; Barsalou et al., 2003; Barsalou et al., 2008; Barsalou et al., 2018).

In the next chapter, I will introduce the situated conceptualization view of constructed emotions as an analytical framework. For now, I turn my attention to a brief review of the various theories of knowledge and mental representation in the psychological sciences. As with the work on emotions, there are many reviews of the various models and theories of conceptual processing in cognitive science and neuroscience (e.g., Barsalou, 2007, 2016c; Dove, 2009; Kiefer & Pulvermüller, 2012; Mahon & Hickok, 2016; Murphy, 2004), and in discussions about word meaning (e.g., Meteyard et al., 2012) and abstract concepts (e.g., Borghi et al., 2017). These go much deeper into the various debates about the nature of mental representations, the interaction between different representational systems, and the role of context, than I am able to here. In the next section, I delve into some of these issues, highlighting those aspects especially relevant to my work in the subsequent chapters.

2.2. Theories of knowledge and mental representation

After decades of behaviourism, the mid-century cognitive revolution brought back the idea that mental operations in the form of mental representations[7] and a representational system that can perform operations on those representations, mediate the relation between human stimulus and response (e.g., Fodor, 1975). These internal representations stand for things in-the-world other than themselves (i.e., have intentional content) providing information that allows the interaction with these to achieve some goal (Barsalou, 1999, 2017a; Prinz, 2004).[8] The basic unit of representation is the concept which roughly stands for the categories into which people differentiate the world (e.g., Goldstone et al., 2013; Murphy, 2004; Prinz, 2004).[9] The human representational system seems to be involved in practically all cognitive

[7] Mental representations are also called internal representations and can be described as predictions within the emergent predictive paradigm of psychology research (Hutchinson & Barrett, 2019).
[8] In this section I focus, for the most part, on Barsalou's account and definitions.
[9] These are all contentious topics. Barsalou and others have suggested that the category of 'concept' is probably not useful for making science (e.g., Barsalou, 1999; Machery, 2009). Barsalou however, still uses concepts with his latest definition of "a dynamical distributed system in

processes, including online processing (e.g., perception, categorization, inferences), offline processing (e.g., semantics, memory, reasoning), and in the productive construction of novel concepts (Barsalou, 1999, 2003, 2007; for reviews see Goldstone et al., 2003; Kiefer & Pulvermüller, 2012). As a consequence, Barsalou, citing Rupert (2011), has argued that the mind and the brain are "massively representational" (Barsalou, 2016b, p. 84) making representations one of the brain's domain-general processes from which emotions are made (Barrett et al., 2014).

While most researchers agree that the representational system is essential to cognition, there is disagreement over its format and function, as well as the content of the representations it produces. In what follows, I focus on four primary debates in this area. First, I investigate whether the format of the representations is *amodal and abstract* or *modal and grounded*. Then I examine different positions concerning the role of language in representation. Third, I look at the relation between concepts and meaning, discussing whether they are contextually dependent. Finally, I briefly explore the current debate over the content of abstract concepts.

2.2.1. Amodal vs modal representations

Early theories of mental representation in cognitive psychology argued that conceptual knowledge is stored in the form of amodal symbols (e.g., Collins & Loftus, 1975; Fodor, 1975; Rosch & Mervis, 1975). Amodal symbols refer to representations that are not bounded by the content of the concept they stand for and have a certain degree of arbitrariness inscribed in them (see Mahon & Hickok, 2016). Various proposals for the form of these amodal symbols exist, such as a feature list (e.g., Rosch & Mervis, 1975) and distributed semantic networks (e.g., Collins & Loftus, 1975). Their central assumption is that the perception of an object (e.g., seeing, smelling, touching a flower or tree or apple) is transduced into a concept (e.g., FLOWER, TREE, APPLE) which is stored in a separate module, usually termed semantic memory, and where the format of storage is as abstract symbols that have no relation to perception or action. These amodal symbols are fully equipped to perform all the computational activity such as productivity functions, type-token distinction, and the constitution of abstract concepts through different operations in a fully-fledged representational system that supports all other cognitive processes, such as memory

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the brain that represents a category in the environment or experience and that controls interactions with the category's instances" (Barsalou, 2016a, p. 11).

and imagination (e.g., Fodor, 1975; Pylyshyn, 1984). Many of these theories have been formalised using logic, probability, and other tools that hinge on a metaphoric understanding of the brain as a digital computer and amodal symbols as its code (e.g., Pylyshyn, 1984).

Multiple theoretical and empirical challenges to the strongest versions of amodal symbols[10] have been mounted in philosophy (e.g., Harnad, 1990; Prinz, 2004; Searle, 1980), cognitive science (e.g., Barsalou, 1999; Zwaan, 2004), and neuroscience (e.g., Pulvermüller, 1999). One primary concern involves the so-called symbol grounding problem (Harnad, 1990): amodal models fail to answer comprehensively how these symbols map onto perception and objects in the real world (Barsalou, 1999). Moreover, strong versions of amodal theories have had to respond to the strong empirical evidence showing the extensive involvement of sensorimotor areas in representational processes (Barsalou, 2007; Kiefer & Pulvermüller, 2012; Meteyard et al., 2012; c.f., Mahon & Caramazza, 2008; Mahon & Hickok, 2016).

The counterparts to these amodal theories of mental representation and concepts have been labelled as embodied[11] or grounded[12] views, which overall argue that mental representations are re-enactments or simulations of multimodal states learned from experience (e.g., Barsalou, 1999, 2007; Gallese & Lakoff, 2005; Prinz, 2004; Zwaan, 2004). While versions of this idea have circulated throughout history (e.g., Hume, Locke) (for a brief historical review, see Barsalou, 2010) over the last few decades these have been brought back to the centre of the debate on human cognition from various disciplines, including linguistics (e.g., Lakoff & M. Johnson, 1980), philosophy (e.g., Prinz, 2004), psychology (e.g., Barsalou, 1999; Paivio, 1971) and neuroscience (e.g., Pulvermüller, 1999). These theories by and large share the idea that mental representations and cognition, in general, are not constituted exclusively by abstract amodal symbols, but rather are made of perceptual symbols grounded in, and distributed across perceptual, motor, affective, and other systems. Empirical evidence

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[10] Meteyard et al. (2012) distinguish between four views of the representational system in relation to the symbols' format. On the one extreme are the strong amodal or disembodied theories (e.g., Collins & Loftus, 1975, Fodor, 1975), while on the other are strong embodiment theories (Gallese & Lakoff, 2005, Zwaan, 2004). The weak embodied and disembodied (amodal) theories lay somewhere between recognising certain levels of association between sensorimotor regions and an amodal (or supramodal) integration. While other authors have criticised this heuristic for its simplicity (e.g., Mahon, 2015) it still helps for thinking about the differences in positions about the format of mental representations.

[11] People mean very different things when they use the term embodiment (Shapiro, 2013). The embodiment view expressed here has been labelled the conceptualization hypothesis (Matheson & Barsalou, 2018), which is concerned for the most part with the nature of mental representations and meaning as sources of causal force. This contrasts with other embodiment perspectives, such as the replacement and constitution views which focus more on the relation between the organism and the environment.

[12] Barsalou argues that the term grounded captures much better the nature of the research "by including other forms of grounding beside embodiment, such as multimodal simulation, physical situations, and social situations" (Barsalou, 2016c, p. 1123).

provides correlational and causal evidence of representations grounded in these systems (Barsalou, 2007, 2016c; Kiefer & Barsalou, 2013; Kiefer & Pulvermüller, 2012; c.f., Dove, 2009; Mahon & Hickok, 2016)[13].

Some theoretical positions with grounded views have found various uses for amodal symbols. Several of these 'hybrid' versions of embodiment include amodal symbols as a source of information in mental representation (e.g., Louwerse, 2008) and support in the simulation of abstract concepts (e.g., Dove, 2009). These hybrid versions contrast with another set of models, those which argue that language and abstract concepts can be represented in a grounded fashion (e.g., Borghi et al., 2019).

2.2.2. The role of language in mental representation

The role of language in mental representation is also a matter of contention. Some of the early models argued that linguistic forms (i.e., words, phrases, sentences) mirror closely the concepts constituted in amodal symbols (e.g., Collins & Loftus, 1975). In many of these proposals, whether concepts were organized in networks, prototypes, or feature lists, language symbols closely resembled this organization. Moreover, many of these earlier theories treated the structures and operations of language as closely resembling the structures and operations done by concepts (e.g., Fodor & Pylyshyn, 1988). This language-as-mapping view (Lupyan & Lewis, 2019) saw language merely as a sort of sticker, not a source of information that could enhance or transform the mental representation.

However, evidence from the distributional models (Andrews et al., 2009; Vigliocco et al., 2009), property verification tasks (e.g., Barsalou & Wiemer-Hastings, 2005; Solomon & Barsalou, 2004), and other conceptual experiments (e.g., Louwerse & Connell, 2011) suggest that mental representations derive information from multiple systems including linguistic symbols (see Dove, 2009; Louwerse, 2008). This has led to a re-thinking of the role of language in conceptual processing.

[13] While there is still a debate about the interpretation of many of these results (Mahon & Caramazza, 2008; Mahon & Hickok, 2016), these have for the most part led to the re-evaluation of many of the previously held amodal views and the appearance of the so-called 'hybrid' accounts of weak disembodiment. These include theories that argue for the offloading information from the representational system to sensorimotor areas (e.g., Machery, 2016) and others that argue for the interaction in shared spaces between amodal symbols and perceptual or motor areas (Leshinskaya & Caramazza, 2016; Mahon, 2015). These more recent models recognise the association of the sensorimotor areas in cognitive representation but maintain an assumption of independence between these areas from amodal systems that do the conceptual processing.

These newer models go beyond the language-as-mapping view; words, phrases, and sentences assume a constitutive role in mental representation. Such proposals include those by Vigliocco et al. (2009) and Dove (2016) in which language resembles traditional amodal symbols, and others that describe it as fully or partially grounded in the mouth (see also Borghi et al., 2019) or in chains of associates (e.g., Connell, 2019; Louwerse, 2011; Louwerse & Connell, 2011). Some of these models increasingly argue that language modulates and transforms mental simulations[14] by processes such as attuning people to conceptual similarities and supporting conceptual inferences (e.g., Dove, 2020; Lupyan, 2012; Lupyan & Lewis, 2019).

To summarize, the evidence suggests that there are multiple representational systems and that language, being one of them, plays an important role in conceptual processing. This has evoked a series of discussions about the degree to which language contributes to conceptual processing and how it is grounded in the modalities. Barsalou et al. (2008) take a middle of the road approach in their Language and Situated Simulation (LASS) proposal, which argues that while language is important in conceptual processing, it is less essential than the simulation of the situation grounded in the modalities. The description and ramifications of this proposal will be further explored in the theoretical and analytical framework chapter.

Whether words act as pointers (Barsalou et al., 2008), maps (Vigliocco & Vinson, 2007), tools (Borghi et al., 2019), cues (Lupyan & Lewis, 2019), labels (Connell, 2019), or neuroenhancements (Dove, 2020), all these hybrid models rely heavily on metaphorical language to capture how the language and the simulation systems interact to produce mental representations. One issue that has not been adequately addressed, however, but that is nonetheless at the centre of these discussions of conceptual processing, is the question about context. Because many cognitive scientists assume that words refer to a mental representation, this issue is intrinsically tied to the deeper question about the meaning of words.

[14] Simulations are the partial re-enactment of grounded knowledge from experience of a category (Barsalou, 1999, 2009).

2.2.3. Concepts, context, and word meanings[15]

There is an ongoing debate in cognitive science regarding the role of context in conceptual processing. The different proposals can be put on a continuum of stability where, at one end, are models assuming an absolute invariance of concepts or 'context independence', and, at the other end, are those that assume total dynamicity or 'context-dependence'[16]. The former end of the spectrum includes semantic memory models, which argue that mental representations have a relatively stable core based on features, lists, prototypes, or another form of knowledge organization (Rosch, 1978; Rosch & Mervis, 1975). According to these theories, concepts are stored in an autonomous system of long-term memory (i.e., semantic memory) in the form of rules of necessary and sufficient features (classical rule-based theories) or of weighted family resemblance structures (prototype theories) (for discussions see Barsalou, 2003; Goldstone et al., 2013). As these theories assume a sort of one-to-one correspondence between concepts and words, communication between members of a community is possible as a result of the stability at the core of their mental representations (Rey, 1983)

On the other end of the spectrum, many grounded models of mental representation argue that concepts are dynamic and situated[17]. Mental representations are constructed as partial re-enactments of previous patterns of activation learned in experience and in relation to the goals of a specific context; meaning that there are no conceptual cores (Barsalou, 2016a; Casasanto & Lupyan, 2015; Connell & Lynott, 2014; Yee & Thompson-Schill, 2016). In that sense, the mental representations which serve as referents of words are always changing in response to the situations in which they are constituted (i.e., they are always ad hoc) (Barsalou, 1983; Casasanto & Lupyan, 2015). The resulting infinite polysemy gives rise to

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[15] In the question about semantics, psychologists, and cognitive scientists tend to oppose many of the traditional theories of word meaning derived from linguistics and philosophy, which for the most part study language "as it occurs" (Pelletier, 2017, p. 43). Many in the latter group take a position known as externalism, wherein the relationship between linguistic forms and mental representation is "far too uncertain, changeable, and individual to serve as a possible object of principled investigation" (Riemer, 2015, p. 5) and instead, focuses on the relationship between words and their referents in the 'external' world. By contrast, many in cognitive science, which is the position taken here, assume that mental representations contain the content of the meaning of words - a position which has been labelled internalism (Pelletier, 2017; Riemer, 2015). The meaning of a word is not an object in the world but rather the object's mental representation in someone's mind (Barsalou, 2017b). This is not to say that all mental representations have words attached to them, but rather that words label some of these mental representations. This is not a straightforward position to take. In some models, the content of a 'mental representation' (i.e., concepts) is separated between conceptual knowledge and linguistic knowledge, while others assume semantics lays only on the simulations (for a recent discussion, see: Meteyard & Vigliocco, 2018).

[16] This is also referred to as the invariantism vs contextualism debate (see Machery, 2015).

[17] It is worth adding here that many models are somewhere in between, including all sorts of mechanisms such as connectionist networks, to give contextual flexibility to concepts with stable cores and explain the many context effects observed in empirical studies (e.g., Medin & Schafer, 1978; for discussions, see Barsalou, 2003; Mahon, 2016)

the problem of communication: if all words can take any meaning, how do we manage to communicate at all? The regularities of situations from our biology and culture, and the role of language and other communicative activities, among other things, serve as anchors that provide enough stability for "good enough" communication to happen (Casasanto & Lupyan, 2015; Connell & Lynott, 2014; Davis & Yee, 2021; see also Ferreira et al., 2002). An increasing number of researchers have reached this same conclusion, which is that, in essence, concepts have no cores and meaning is always ad hoc.

2.2.4. Abstract concepts

One challenge to grounded theories is the question of abstract concepts (Borghi et al., 2017; c.f., Dove, 2009, 2016; Mahon, 2015; Mahon & Caramazza, 2008). Abstract concepts are usually defined as the opposite of concrete concepts, in which the referent of the word that stands for the concept can be experienced through one of the exteroceptive senses (e.g., Brysbaert et al., 2014). The concreteness of a word is usually assessed in tasks whereby participants are given lists of words and asked to rank their materiality using point scales (e.g., Altarriba et al., 1999; Paivio et al., 1968). Words that present low averages on these concreteness scales are considered to stand for abstract concepts. Supporters of the amodal view have debated how mental representations for categories without sensory referents, such as 'freedom', 'gist', or 'vanity', are grounded (see Dove, 2009, 2016; Mahon & Caramazza, 2008). Considering that emotion categories such as 'joy', 'grief', and 'shame' tend to score on the low end of the spectrum in these concreteness scales (see Brysbaert et al., 2014) and that Barrett and colleagues treat emotions as abstract categories (Barrett et al., 2014; Hoemann, Wu et al., 2020; Wilson-Mendenhall et al., 2011), it is important to examine the different theoretical positions around the nature and representation of abstract concepts.

Amodal symbols can allegedly effortlessly manage the levels of abstraction required to handle non-perceptual material (e.g., Dove, 2009). However, grounded theories of mental representation have come up with multiple proposals to deal with the problems posed by these concepts. One early proposal argued that abstract concepts can be reflections of concrete concepts grounded in the sensorimotor apparatus through metaphorical language (e.g., Lakoff & M. Johnson, 1980). Metaphors, however, seem limited in their potential to describe the diversity and multiplicity of abstract concepts (for a discussion, see Barsalou, 1999, Dove, 2016). Another approach has been to ground abstract concepts in elements of internal experience. Such elements have included introspection (e.g., values, beliefs) (e.g., Barsalou, 1999; Barsalou & Wiemer-Hastings, 2005), affective states (e.g., Kousta et al., 2011; Vigliocco et al., 2014), and metacognition (i.e., the ability to track cognitive states) (Borghi et al., 2018). This approach has been relatively successful, as some empirical evidence suggests that abstract concepts can be bootstrapped to affective states (Kousta et al., 2011) and introspection (Zdrazilova et al., 2018). The third line of proposals are those which argue that abstract concepts can be represented through language. These claims are often in the form of those previously presented hybrid models that include both linguistic representations and simulation, and in which things like the distributional structure of language (Andrews et al., 2009) or the work words perform in social contexts (e.g., Borghi et al., 2019) contribute to the flexibility of the conceptual system, providing knowledge, and allowing the construction of concepts whose referents cannot be related to the senses. Whether through metaphors, internal experience, or language, most observers agree that the representation of abstract words probably requires the use of a combination of all sources of information, each contributing to different degrees in the various contexts and tasks where the different forms of abstract concepts appear (for a discussion, see Dove, 2016).

A complementary proposal grounds abstract concepts through the various modalities in the elements of a situation. For a while, empirical evidence has recognised the importance of context in constructing concepts in general and abstract concepts in particular (e.g., Barsalou & Wiemer-Hastings, 2005; Wiemer-Hastings & Xu, 2005; for a review, see Yee & Thompson-Schill, 2016). The dynamicity of conceptualization in relation to the context in grounded models synergistically fits the ideas of situated cognition, which give background situations a central role in the processes of the representational system (Barsalou, 2003, 2009, 2016a, 2019; Barsalou et al., 2018; Yeh & Barsalou, 2006). According to this view, concepts are not processed in isolation as a list of their properties, but rather, conceptual knowledge includes all sorts of external and internal situational elements from the context where the category is encountered, including the settings, objects, actions, emotions, and motivations surrounding the occasion. This model recognises a person’s embeddedness in its context, highlighting the role of the representational system to support situated action and bridging the analytical divide between mental processes, the body, and the environment (Barsalou, 2009, 2016a, 2016b).

While the situated conceptualization framework will be further developed in the next chapter, it is important to note that the latest iteration of this model regards the distinction between abstract and concrete concepts as a 'misnomer' (Kiefer & Barsalou, 2013) and argues for moving beyond this distinction (Barsalou et al., 2018). Because both abstract and concrete concepts are grounded in situations, and situations include both external and internal elements, all concepts include elements that are stereotypically considered concrete and abstract to a different degree; there is no real boundary between these two kinds of concepts.

Overall, the cumulative body of work reviewed suggests the multiplicity of available frameworks through which to describe the human representational system. The most recent iterations seem to have moved away from amodal symbols and embraced the multiple sources of information that contribute to the construction of mental representations. Most importantly, the newest models seem to agree that concepts and meanings are constructed ad hoc and that abstract concepts, such as emotions, incorporate elements from the context that are both internal and external. Capturing all these developments, Barsalou's situated conceptualization framework (2005; 2009. 2016a), I believe is the best framework suited to the task of describing how the representational system works. This framework will be further developed in chapter three. For now, however, I turn my attention to the science communication literature, assessing the theoretical discussion about this emerging discipline and how emotions factor into its study.

2.3. The study of science communication

At the centre of this thesis is the conceptualization of science communication as a cultural mosaic composed of a collection of subcultural spaces. However, to show how I arrive at this perspective, it must be contrasted with the dominant view of science communication as a series of models for transferring information (Bucchi, 2008; Trench, 2008). Discussions about the values, goals, and worldviews implicit in each of these models serve as a vehicle towards reframing science communication as culture. As such, in this section, I review the main framework currently used to describe science communication. I then present several alternative conceptualizations, particularly those that approximate my definition of science communication as culture. Following this, I develop my framework for studying science communication in chapter three.

2.3.1. The three-model view of science communication

The study of science communication as a subdiscipline is relatively recent[18]. It was only in the early 1990s with the appearance of the first journal dedicated exclusively to science communication – *The Public Understanding of Science* – when a systematic theoretical and empirical program of assessing the public communication of science acquired its own identity (Bucchi, 2008). In its effort to distinguish the communication of science from the communication of other social practices (e.g., politics, sports, fashion), the newly minted discipline introduced various frameworks to articulate its nature.

Much of what has been written about the theoretical underpinnings of science communication has defined communication in terms of the transfer of knowledge (Bucchi, 2008). Initially introduced in Shannon and Weaver's *Mathematical Theory of Communication* (1963), early transmission models of communication describe it as a simple linear one-way line between two points. Further theoretical developments increased the model's complexity, assuming multiple communication channels coming from different sources and interacting in parallel, drawing a richer ecosystem of networked sources, mediums, and arrangements for conveying information between different actors. The development of the three main models of science communication – from *deficit* to *dialogue* and *participation* – corresponds to these developments from simple linear one-way models of communication as transmission to its more sophisticated networked versions.

These three models have been constitutive of both the study and practice of science communication. Trench (2008) describes them as part of a 'grand narrative' of the discipline, whereby before the 1990s, most science communication practices were conceptualised using the deficit model (experts filling "knowledge gaps" of non-expert audiences), but since then, there has been a trend towards more dialogic and inclusive forms of engagement. This narrative has established the limits of the field, constituted the identities of its scholars and practitioners, and established many of the practices through which science communication regulates itself (Davies & Horst, 2016); it is still very much part of the language used in the field both by academics and practitioners, serving as the discipline's shared collection of

[18] Work in the rhetoric of science, the philosophy of science, the history of science, science education, science and technology studies and communication studies touched on issues about the communication of science to non-scientists before the creation of science communication as a subdiscipline (e.g., Funkhouser & Maccoby, 1971; Lessl, 1985; Tannenbaum, 1963).

meanings that constitute much of its practices and analytical frameworks (Davies & Horst, 2016; Perrault, 2013; Trench, 2008).

Notably, each of the three models is sometimes presented as having different, contrasting, and competing sets of values, beliefs, norms, goals, and worldviews (i.e., cultural mandates) (e.g., Perrault, 2013; Metcalfe, 2019, Trench, 2008). These reflect deeper ideas about the aims of science communication, how it should be practised, and its value in our societies, among other things (see Davies, 2021; Medvecky & Leach, 2019; Perrault, 2013). In that sense, deficit-style models have been characterized as paternalistic, top-down, hierarchical, and instrumental (e.g., Hilgartner, 1990) while dialogic and participatory models are generally described as tending towards more egalitarian and democratic worldviews (e.g., Durant, 1999; Priest, 2018). Although the classification of science communication activities in a tri-partite model and the unidimensional dichotomization of their ideological shell masks the heterogeneity and complexity of the cultural mandates in its practices and products (see Davies, 2021), this taxonomy serves as a steppingstone towards the conceptualization of science communication as a mosaic cultural space with a wide variety of values, beliefs, norms, goals, and worldviews.

In what follows, I briefly describe these three ways of thinking about and practising science communication, reviewing some of their cultural mandates, and highlighting some of the challenges presented to each of these. I will argue that a reconceptualization of these models in terms of the values, beliefs, norms, goals, and worldviews shared by researchers and practitioners, can set the stage for the constructionist conceptualization of science communication as a multiplicity of cultural spaces developed in the next chapter.

2.3.1.1. The deficit model of science communication

The deficit model[19] presupposes the existence of two kinds of people: the scientist and the general public. The former is envisioned as having important scientific knowledge that the

[19] After various surveys through the 70s and 80s consistently showed little improvement in the general population's scientific knowledge in countries such as the United States and the United Kingdom, the science literacy movement galvanized in these countries to push for increasing the levels of public knowledge of basic scientific facts, processes, and science-related policy issues (S. Miller, 2001). This was a concerted public effort to increase scientific knowledge both through education and communication campaigns; efforts which were epitomized in the work of J.D. Miller (1983) and the *Public Understanding of Science* (PUS) movement (Bodmer, 1985) who argued that science communication should encourage people to make better rational decisions, have a basic knowledge of scientific facts accompanied by positive attitudes towards science, support technocracy as a form of management of public affairs, reject superstition and pseudoscience, and increase support for national scientific output through investment and career choices, among other things (see Bauer et al., 2007; Logan, 2001; Metcalfe, 2019).

latter does not (Bucchi, 2008; Trench, 2008). Because scientific knowledge is seen as rational, objective, and progressive, the content of the 'science of the day' is universal and hence communicable in every context without much alteration (Bucchi, 2008). This black-box version of science does not account for the many social, political and economic aspects of how science is made, the uncertainty in its results, and the idiosyncrasies and biases of scientists, among other things (Perrault, 2013). Furthermore, although the general public is understood as a passive actor, they are rational nonetheless, hence they take incoming scientific information a-critically, as they are thought to understand this type of knowledge as superior to other forms. A form of positivism and scientism serves then as much of the ideological backdrop to the cultural mandates behind the deficit model (Perrault, 2013; Trench, 2008; Wynne, 2006)[20].

According to these deficit-style views of science communication, its products and practices serve a variety of functions that aim primarily at sustaining the privileged place of science in society. The public is ignorant or even hostile about science; a problem that is fixed through communicating effectively the 'science of the day' to either fill in the 'knowledge gap' or to change their beliefs and behaviours that are seen as irrational or noxious (Bucchi, 2008; Lewenstein, 2003; Nisbet & Scheufele, 2009). Moreover, deficit-style science communication also aims at cementing the provision of political, financial, and human resources to maintain and increase scientific activity. This is done through activities that increase support for science funding (Scheufele, 2014), promote science as a potential career choice (Trench & Junker, 2001), and market science in ways that grow the public's positive attitudes towards it (Trench, 2008), among other things (see Metcalfe, 2019). Instrumental and strategic concerns characterize many of the goals of much of this type of science communication (see Priest, 2018). More importantly, many of the values, beliefs, norms and goals underwritten in deficit-style practices constitute hierarchically structured dynamics such as those between scientists and the public, knowers and learners, and science and society (Hilgartner, 1990).

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[20] Perrault (2013) links the deficit model to an attitude of science boosterism, whereby communication practices revel in the wonders of science and practitioners see themselves as filling in a lack or void in consumers' minds (Perrault, 2013). Popular symbols of science communication such as the TV series *NOVA*, outlets such as *Scientific American*, and the work of science popularisers such as Carl Sagan and Richard Dawkins are usually given as examples of this way of thinking (Nisbet & Scheufele, 2009; Perrault, 2013).

Many of the issues that have been identified with deficit-style science communication practices and research have to do with these hierarchical ideological underpinnings. First of all, the model defines scientists and the public in a very broad and homogenous way (Perrault, 2013). It does not recognize that scientists outside their field of speciality are part of the public, and that the public includes various stakeholder groups that have different degrees of interest in the scientific topics of the day. Second, it ignores that communication, besides being non-linear, is also neither a discrete nor a one-way process (Bucchi, 2008; Trench, 2008). The different actors provide and receive continuous feedback through which they constantly adjust their messaging. This view rather presents a static view of science communication that fails to allow for the gradual shifts that occur in the way messages are performed and packaged. Third, the deficit model also mostly overlooks the contexts in which science communication occurs (Lewenstein, 2003). For the most part, the histories, idiosyncrasies, and social conditions of the people involved are not considered (Nisbet & Scheufele, 2009). Replacing the diverse, non-linear, and networked contexts in which different sociocultural realities meet in science communication for a stratified, static, and simplistic view of communication is perhaps the reason why the deficit model fails to engage people in the way that practitioners aspire (Lewenstein, 2003; Perrault, 2013).

Despite this, the deficit model continues to be the preferred model for science communication, not just in its practices (Simis et al., 2016), but also research on science communication, which continues to frame the discipline in terms of audience knowledge gaps (Suldovsky, 2016). In many studies, the public is problematized as irrational, biased, and subjective, needing to be cured at an individual level (F. Mellor, 2018). This view does not acknowledge the role that cultural, social, and political forces play in the contexts in which science gets communicated, driving researchers towards simplistic laboratory stimulus-response studies (see Chapman et al., 2017). Importantly, this issue disregards qualitative case studies that may give a much more complete, and complex, picture of how scientific knowledge is communicated in specific contexts (Lewenstein, 2017). Problematizing the public as the source of conflict, seeing science as a black-box, and not acknowledging the many contextual factors involved in the science being communicated, are just some of the many lingering issues that reveal the ideological commitment of the deficit model to the sustenance of a hierarchical practice of science communication.

2.3.1.2. The dialogue model of science communication

By the late 1990s, the *Biotechnology and Biological Sciences Research Council* (BBSRC) suggested the need to "enhance public access to science and scientists with a view to improving public confidence and stimulating open debate about science and technology" (Trench, 2006, p. 2). This signalled an already occurring move[21] in the practice of science communication, from a top-down, one-way, homogenous streak, towards an open, two-way conversation, known as the transition "from deficit to dialogue" (Trench, 2008, p. 120).

This change translated into public outreach programs, consensus conferencing, national hearings, focus groups, open debates, *cafés scientifique*, and various other formats that function to reapproach the scientific community and the public on a variety of issues, such as genetically modified foods (e.g., Horlick-Jones et al., 2007) and nanotechnology (e.g., Krabbenborg, 2012). This includes activities aimed at gaining insight into different public attitudes and beliefs of science (Bucchi, 2008, Scheufele, 2014) and learning from lay-experts (Irwin, 2014; Trench & Junker, 2001). Importantly, issues of trust became central to discussions about the goals of science communication (Wynne, 2006). Science museums, research institutions, universities, and other organizations seeking to improve people's attitudes towards science and scientists, also turned to engagement activities, such as science festivals (e.g., Bultitude et al., 2011), education outreach (e.g., Jeffers et al., 2004), and social media (e.g., Brossard, 2013), whereby science communicators interact regularly with target audiences to cultivate their trust. In parallel, there were numerous calls for science communication to function as a place for the transparency and accountability of science towards the public (Bucchi, 2008). Today, the language of dialogue, which questions much of the hierarchical worldview of deficit-style science communication, is deeply embedded in many science communication practices (Irwin, 2014).

However, various issues have been pointed out about a dialogic understanding of science communication. Perrault (2013) points out that as with the deficit models, science in most dialogue models is still seen as an unproblematic institution. Engagement is then a potential manipulative tool for reaching a specific political, financial, or ideological goal that could

[21] After a series of science-related issues that undermined public trust in science starting in the 1980s (e.g., *Bhopal* crisis, AIDS, 'mad cow disease'), new forms of relations between scientists and society had begun to be explored in the UK and US (Davies & Horst, 2016; Stocklmayer, 2018).

arise from related scientific research. Issues about the science that might cast doubt over its practices and products are usually assuaged or ignored. In that sense, scientism and technocracy continue being much of the ideological underpinnings of this form of science communication. While the goal of the dialogue models is not getting people to "simply" understand the science of the day, its aims can still be dubious, especially if it fosters uncritical views of the science at hand (Lewenstein, 2003; Perrault, 2013)[22].

More importantly, dialogic views of science communication continue focusing on public deficits; not about knowledge but rather about issues such as engagement and trust (Bauer et al., 2007; Davies, 2011; Wynne, 2006). Over the past few decades, researchers of science communication have become increasingly concerned with measuring people's confidence, agreement, expectations, and support for scientific practices and products, measured through batteries of multi-dimensional attitude questionnaires that have tried to capture the public's general demeanour towards science (e.g., Hendriks et al., 2016). Although many of these studies try to incorporate the psychological complexity of the relation between the audiences and science, contextualizing this dynamic by adding measures on people's values, identity, and worldviews to their surveys, these continue to rely on the assumption that science communication should aim at changing the public's minds, and that the public should go through this attitudinal and belief transformation (Perrault, 2013).

In sum, dialogue-style practices are usually recognized as an improvement over the deficit-style hierarchical view of science communication (e.g., Lewenstein, 2003; Perrault, 2013). However, these do not fully commit towards establishing an even relation between science and the public, open spaces for a critical assessment of the issues, or acknowledge the fluidity of the communicative activity. Addressing the continuation of some of these imbalances is much of the goal of participation models of science communication, which I review in the next section.

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[22] Questions about the efficacy of its practices have also been raised. Dialogue events are supposed to foster different forms of feedback from the public. The question about how much of the feedback gets taken into account into the products and practices of science is a question that is up for debate (see Einsiedel, 2008). Moreover, it is unclear whether dialogic activities such as festivals, actually change the public's views, attitudes, trust, or knowledge around science issues (e.g., Wiehe, 2014). While some evidence suggests the importance of engagement activities assuaging people's concerns and improving their attitudes about an issue (e.g., Walls et al., 2010), other studies also suggest these fall short on many of their promises (e.g., Kurath & Gisler, 2009).

2.3.1.3. Participatory models of science communication

The participation model is, in many ways, an extension of the dialogue model. Both can exist in a continuum of two-way engagement activities where both scientific knowledge and various audiences interact (Trench, 2008). However, the power relations between actors in these two models are conceptualised differently. Whereas in the dialogue model decisions are ultimately placed in the realm of science, the participatory model of science communication takes power away from the scientist and places it with other stakeholders – many times those who have been traditionally disempowered as players within the deliberation process (Davies & Horst, 2016). Here, the public's knowledge is not seen as of inferior value but rather qualitatively different from scientific knowledge (Bucchi, 2008). Herein is the main difference between the dialogue and participatory models of science. While the former takes many of the power asymmetries for granted, the latter aims to solve, or at least recognise, the existence of such differences in part through practices of co-production of knowledge (Bucchi, 2008; Durant, 1999). This kind of democratic and egalitarian worldviews permeate participation-style practices, aiming to redress some of the many social, economic, and political inequalities that science and its communication have generated and helped perpetuate.

The co-production of knowledge in the participation models occurs within a network of participants in multidimensional spaces where interactions are open-ended, continuous, and potentially conflictual (Bucchi, 2008; Bucchi & Neresini, 2007; Davies & Horst, 2016; Metcalfe, 2019; Perrault, 2013). The direct relationship between scientific knowledge and the public disappear, complicating the dynamics between the many actors through time, and constraining the parsimony of linear representations of this relationship. Moreover, thinking of the cultural dynamics in these interactions means that science is not treated as a 'black-box' in these formats (Perrault, 2013). Rather, science is seen as a cultural institution, where experts are treated like any other member of society, and techno-scientific issues are dealt as having a political nature (Bucchi & Neresini, 2008). This opens science up to scrutiny, given that other stakeholders can critically assess the practices, norms, and ideas in their merits and failings, being able to raise concerns about risk, ethics, equity, participation, legitimacy, transparency, or other issues that may arise in the interface between science and society (Einsiedel, 2008). Subsequently, one of the main goals of participatory-style models is to emphasize, not just the technical aspects of scientific knowledge, but also the social, political, and economic aspects of science (Nisbet and Scheufele, 2009) and criticize science when it is due (Perrault, 2013).

There are issues, however, with participatory-style models. Besides the costs and scalability that they share with dialogic models (France et al., 2017; Nisbet & Scheufele, 2009), certain actors feel challenged due to participatory formats' open-ended and political nature, where conflict is an inherent feature. Individuals and institutions not comfortable with these may feel an urge to "tame unruly public participation" (Bucchi & Neresini, 2008, p. 463) through the sponsoring of very formal activities. These sponsored formats may hide the fact that institutions have already taken decisions beforehand, with these formats becoming a cover for public legitimation (Bucchi & Neresini, 2008). Many participatory activities then tend to devolve into a dialogic format. This relates to perhaps a more insidious issue about participatory frameworks in that many such practices mask the power imbalances that exist through society (Davies & Horst, 2016). While many of these formats explicitly state the role of levelling the playing field for the various stakeholders, these can also create the "illusion of a dominance-free space" (Phillips, 2011, pp. 53–54) hiding the many deep social, economic, cultural, and political inequalities that exist in contemporary societies. While some practical issues of participation formats have straightforward solutions in terms of, opening spaces, getting access to resources, and changing how participatory spaces are set up, others such as the many entrenched and unstated power asymmetries of participatory forums where science knowledge is part of the discussion may be harder to recognise and tackle.

Together, the deficit, dialogue, and participatory models of science communication represent the central attempts by the discipline to categorise and understand the different science communication formats, processes, and functions, in a taxonomy that allows for a structured analysis of the many spaces where these activities take place while at the same time creating a coherent narrative of the discipline's evolution through time (Davies & Horst, 2016). However, various authors have pointed out the many issues confronting this classification scheme that go from its lack of historical awareness to their use of a limited definition of communication (e.g., Broks, 2006; Bucchi, 2008; Davies & Horst, 2016; Horst & Michael, 2011; Michael, 2002; Trench, 2008). There are many reasons why these models have been so pervasive in science communication research, including the influence of transfer metaphors in the English language (Bucchi, 2008) the very short time the field has been around, having to relive the entire history of communication studies in just three decades (Trench, 2006), and the force that the 'from deficit to dialogue' grand narrative has had in the demarcation and constitution of the field (Davies & Horst, 2016; Trench, 2008).

While imperfect, however, these three models can be seen as reflecting the contrasting and competing sets of values, beliefs, norms, goals, and worldviews present in science communication that serve as a backdrop to many of its products and practices (see Metcalfe, 2019). While the ideological core in many deficit-style activities reflects a top-down understanding of science communication's role in society, dialogic- and participatory-style conventions address in different ways some of these hierarchies. The cited studies that have pointed towards the various worldviews and cultural mandates that permeate each of these three different models serve as a steppingstone that moves us away from the conceptualization of communication as transmission, towards rethinking of science communication as a mosaic cultural space.

2.3.2. The study of science communication as culture

Over the last few decades, an increasing number of researchers have questioned the transfer metaphor and begun to frame research in terms of meaning-making. These authors have asked questions about the role of science communication in the formation of identity (e.g., Davies & Horst, 2016), the preservation of power structures (e.g., Hilgartner, 1990; Wynne, 1992) and the circulation of different discourses (e.g., Fuller, 1998; Myers, 2003; Perrault, 2013) among other issues. They also have highlighted the importance of practices such as ritual (e.g., Blue, 2019) and performance (e.g., Hilgartner, 2000), analysed the production, circulation, and consumption of cultural artefacts (e.g., Macdonald, 2002) and observed differences in epistemologies (e.g., Jasanoff, 2011) and framing schemas (e.g., Nisbet et al., 2009). This 'cultural turn' in science communication studies (Blue, 2019, p. 4) has highlighted the need for new analytical frameworks to study the subject.

Various authors have taken the task of proposing new analytical frameworks for studying science communications that go beyond the three-partite model. Some of these propose studying science communication as an emergent event (Horst & Michael, 2011) using actor-network theories to describe it (Davies, 2018), rethinking the practices in terms of Carey's ritual views on communication (Blue, 2019), conceptualising a hybrid model whereby humans and non-humans interact as rhizomic organisms (Michael, 2002) or through a koru model that uses a tree as a metaphor for the interconnectedness and flow of its many products and practices (Longnecker, 2016). More recently, research has begun to focus on the communicative values, goals, and worldviews that permeate science communication activities. These have come up with taxonomies that acknowledge the variety of cultural mandates beyond the 'from deficit to dialogue and participation' narrative (e.g., Davies, 2021). These recent re-conceptualizations of science communication are trying to move the researcher's attention to the role of meaning-making, addressing the representational systems and ideologies that permeate much of its practices and products, and situating its different manifestations in context.

In the theoretical and analytical framework chapter, I will introduce a constructionist version of science communication as a mosaic cultural space, borrowing from theorists such as historian Peter Broks (2006), STS scholars Sara Davies and Maja Horst (2016), rhetorician Sarah Tinker Perrault (2013), and science education researcher Glen Aikenhead (1996), among others. In doing so, I aim to position science communication properly as a distinctive cultural space, one held together, constituted, and reconstituted by a shared set of meanings, passed on to others through social learning in the practices and products of this space. More importantly, I will argue that science communication is composed of a mosaic of subcultures, each of which contains different cultural mandates and which are in constant interaction within larger cultural frameworks.

For now, I turn to the final section of this literature review, where I provide a brief overview of the study of emotions in science communication, drawing more closely toward my particular empirical focus on the role of awe in the culture of science communication.

2.3.3. Emotions in science communication research

Although a complete review of the research of emotion in science communication is well beyond the scope of this research, it is worth highlighting that, for the most part, these studies take the classical view of emotions and a transmission understanding of communication. Most of these studies can be organised into three groups. First is the research that investigates the role of emotions in the processing and communication of risk information. Empirical studies that have looked at the role of emotions and affect in risk processing have been relatively common in health communication (e.g., Witte & Allen, 2000) and most recently in environmental communication, in particular, climate change communication (e.g., Leiserowitz, 2006; Meijnders et al., 2001). Risk communication is the most robust area in the study of emotions in science communication yet has relatively low relevance to the present thesis.

Second is the literature that examines the role of emotions in the formation and change of people's knowledge, beliefs, motivations, perceptions, behaviours, and other cognitive processes on various science communication topics. These studies have used both correlational (e.g., Doherty & Clayton, 2011, N. Smith & Leiserowitz, 2014, Ojala, 2012) and experimental methods (Bilandzic et al., 2017, O'Neill & Nicholson-Cole, 2009, Lu & Schuldt, 2015) to describe the relationship between emotions such as hope, guilt, fear, and grief and a particular cognitive event. Overall, these studies have observed how emotions and messages framed to elicit emotional reactions can have a persuasive effect, changing people's attitudes and behaviours towards science-related topics such as climate change.

The instrumentalist view of emotions taken in most of these studies, however, has been criticised for ignoring the complexities of the interactions between context, cognition, and affect, for disregarding the ethical issues that manipulations of this sort might invoke, and for discounting the wealth of moral knowledge that emotions can contribute to important discussions about issues as urgent as climate change (Chapman et al., 2017; Roeser, 2012). These studies have treated emotions as "simple levers to be pulled to promote the desired outcomes" (Chapman et al., 2017, p. 850) rather than being part of a "more complex and integrated interpretive and learning system" (Chapman et al., 2017, p. 851). For most of these studies, emotions are either catalysts or barriers to the effective transfer of information, failing to consider the contextual dynamics of meaning-making processes, the cultural and historical contingent nature of the categories of emotion used, and the variety of ways in which these are experienced and expressed, among other things.

Finally, some studies have looked at how people and cultural artefacts represent emotions on topics related to science communication. For example, studies of social representations of climate change done through interviews of people in various European countries (Fischer et al., 2012), adults in a small rural community (Norgaard, 2006), industry scientists and engineers (Lefsrud & R. E. Meyer, 2012) and Tibetan villagers (Byg & Salick, 2009) have found the critical role that emotion categories such as anxiety, fear, guilt, and worry, play in how these participants talked about climate change (Wang et al., 2018). Similarly, in interviews with science communicators and members of the public, Davies (2019) identified the negotiated nature of how people talk about emotional states such as wonder and interest at science events. In addition, a few studies have investigated representations of emotions in science communication cultural artefacts. Thagard (2002), for example, examined the word counts of stereotypically positive and negative emotion categories in James Watson's classic book *The Double Helix*. The author found that emotion words, particularly positive emotions such as happiness and interest, were common in the description of scientific work, with both positive and negative emotions used to describe the scientist's motivations. In another study related to climate change, Höijer (2010) observed in the Swedish press and television how this issue's communication is often anchored on emotions such as compassion, fear, guilt, hope, and nostalgia. Most recently, researchers have begun to look for representations of emotion in a broader variety of science communication cultural artefacts, including comments on social media websites (Hwong et al., 2017), non-fictional medical television programs (Verhoeven, 2008), and pop music (Huang & Allgaier, 2014).

While some of this work acknowledges the impact of emotions in the construction of people's perception of risk (e.g., Görke & Ruhrmann, 2003), their construction of climate change (e.g., Nerlich & Jaspal, 2014), and in the constitution of identity (e.g., Lefsrud & R. E. Meyer, 2012; Norgaard, 2006), no study has looked at the learning of emotions from their engagement with science communication or the distinct and various ways in which these are represented within this cultural space. Rather, emotions are largely taken for granted as universal categories existing a priori, utilising variations of the classical view of emotions including explicitly naming basic emotions theories (e.g., Nabi et al., 2018; N. Smith & Leiserowitz, 2014) or appraisal models (e.g., Bilandzic et al., 2017; Feldman & Hart, 2015; Lu & Schuldt, 2015; Volkman & Parrott, 2012) or rather implicitly without describing their nature (e.g., Davies, 2019; Simons et al., 2009; N. Smith et al., 2011; Thagard, 2002). Even those studies that have suggested a reassessment of the way emotions are treated in science communication in general, and climate change communication in particular (e.g., Roeser, 2012), ignore the various developments of affective sciences and the constructionist views of emotion (c.f., Chapman et al., 2017). While there is an increasing interest in including emotions in the study of science communication (Davies et al., 2019), no research program has taken these developments seriously into account. In that sense, this thesis is the first attempt to use the constructionist account of emotions to study their role in the communication of science.

2.4. Conclusion

In this first chapter, I have combed through a large swath of various literatures to describe the theoretical, analytical, and scholarly space that my work occupies. I critically assessed how most work on awe and emotions in science communication has taken a classical view of emotions – an increasingly outmoded paradigm for doing emotion research. Similarly, I observed how science communication research can move beyond the transfer metaphor using the deficit to dialogue to participation story as a steppingstone to the description of science communication as a mosaic culture with various subcultural spaces. Describing what came before, I can now move forward with presenting the framework used in my analysis: the situated conceptualization take of the constructionist view of emotions (particularly applied to the affective state of awe), as well as a constructionist argument to describe science communication as a mosaic cultural space.

3. Introduction

In this chapter, I present the theoretical and analytical framework underlying the studies in this thesis. First, I introduce Barsalou's (2005, 2009, 2016a) grounded cognition model known as *situated conceptualization*. In particular, I focus on two aspects of this theoretical framework: the language and situated simulation theory (or LASS; Barsalou et al., 2008) and the brain as situation processing architecture hypothesis (or BASPA; Barsalou et al., 2018). In the next section, I present a version of the constructionist view of emotions which combines ideas from different authors. Here, I focus on the work of Barrett and her colleagues (e.g., Barrett, 2006b, 2012, 2017a; Gendron et al., 2020; Gendron & Barrett, 2018; Hoemann et al., 2019), which describes how a brain, wired by culture, constructs emotions as the result of the combination of various domain-general processes. I complement this material with other constructionist models of emotion that highlight how a culture moulds and constrains the construction of emotion (Mesquita et al., 2016; 2017) and how it can be understood as a kind of skill that is learned and cultivated (Hoemann et al., 2019; Hoemann, Nielson, et al., 2020). I conclude this section by proposing the situated conceptualization framework as an analytical scaffolding to the constructionist view of emotion presented in this chapter (see Lebois et al., 2018; Wilson-Mendenhall et al., 2011).

I then turn my attention to the study of science communication from a constructionist perspective. Synthesizing different literatures, I conceptualize science communication as a mosaic cultural space nesting a variety of subcultural spheres with contrasting and competing cultural mandates and worldviews. I conclude with a brief integration exercise, putting together the constructionist view of emotions and science communication, to illustrate how awe is represented both mentally and socially in this cultural space.

3.1. The situated conceptualization framework

Barsalou's situated conceptualization theory[23] (e.g., Barsalou, 2003; Barsalou et al., 2008; Barsalou, 2009, 2016a; Barsalou & Wiemer-Hastings, 2005; Yeh & Barsalou, 2006) is

[23] Although the situated conceptualization theory is arguably the best approximation we currently have of conceptual processing, multiple criticisms have been levied against the work of grounded cognition in general, and Barsalou's work in particular. Scholars, for example, point out that the theory fails to acknowledge the possibility of amodal symbols (e.g., Dove, 2009; Machery, 2016), gives only a secondary role to language (e.g., Borghi et al., 2019; Dove, 2020; Lupyan, 2019), does not have a clear explanation for abstract concepts (e.g., Dove,

largely an attempt to bridge grounded theories of knowledge (e.g., Barsalou, 1999, 2007; Prinz, 2004) with the physical and social environment in which the body is situated (e.g., Gibson, 1979). At the core of this framework is the idea that the human conceptual system evolved to support perception, cognition, and other processes that stand between stimuli and outcomes in the form of goal-directed action (see Barsalou, 2016b). This then is a comprehensive theory, one that not only accounts for mental representations and their role in cognitive, perceptual, and motor processes, but also connects a person's internal milieu to the external physical and social worlds in which their body is located (Barsalou, 2016a, 2017a).

3.1.1. Categories, conceptual knowledge, and concepts

The human conceptual system holds the knowledge that people have acquired through experience in memory and uses this knowledge to support both basic and high-level cognitive processes (Barsalou, 2012). Barsalou (2016b) distinguishes between two kinds of processes in the conceptual system, which I will refer to as *conceptual knowledge* and *concepts*. The repeated interaction with a category in the external world (e.g., agents, objects, events) and mental experience (e.g., affect, metacognition) constitutes the conceptual knowledge of the category. This is stored in distributed systems in the form of a full brain mental representation (Barsalou, 2016a, 2016b, 2017b; Barsalou et al., 2018; Simmons & Barsalou, 2003)[24]. Statistical learning mechanisms continuously encode conceptual knowledge in the brain in the form of a population of exemplars and limited abstractions that are dynamically changing as a person accumulates experiences throughout their lifetime with the category (e.g., Aslin, 2017; Barsalou, 1999; Xu & Kushnir, 2013). Mechanisms such as language, the brain's organization, and the basic operations of the conceptual system (e.g., categorization, inference, propositions, productivity) constrain, modulate, and dynamically fine-tune the content of conceptual knowledge (e.g., Barsalou, 1999; Lupyan & Lewis, 2019; Simmons & Barsalou, 2003). Conceptual knowledge never remains static, dynamically changing through a person's lifetime as more exemplars, and more finely tuned abstractions accumulate (see also Connell & Lynott, 2014).

2016; Löhr, 2019; Mahon & Caramazza, 2008), and does not recognise conceptual cores (e.g., Machery, 2015) (see the previous chapter). However, Barsalou's account is, in my opinion, the most compelling to date, as it is backed by considerable empirical evidence (see Barsalou, 2003, 2007, 2020) and avoids the "quixotic dead ends" (Barsalou, 2016, p. 1122) of amodal theories and abstract concepts.

[24] This is similar to the idea of simulators in some presentations (Barsalou, 1999). The language used here is closer to that used in various constructionist views of emotion (e.g., Barrett et al., 2014).

Moreover, conceptual knowledge is stored throughout the brain within multiple representational systems. In particular, the simulation system grounded in the modalities, and the language system (Barsalou et al., 2008). The information of the simulations is distributed in representations in the various sensory-motor and interoceptive systems (e.g., smelling a rose, touching a rose, seeing a rose, holding a rose, feeling excitement for a rose) (Barsalou, 1999, 2003) while linguistic information is encoded in its statistical relationships present in language use (Andrews et al., 2009; Connell & Lynott, 2013; Louwerse, 2008, 2011; Vigliocco et al., 2009)[25]. Conceptual knowledge in this framework is not the abstract symbols of amodal theories (c.f., Mahon, 2015, Machery, 2016) but is instead grounded in people's perceptual, motor, interoceptive, social, and linguistic experiences[26] (see also, Borghi et al., 2017).

On certain occasions, a small subset of conceptual knowledge of a category becomes activated to construct a multimodal concept representing the category (Barsalou, 2009, 2016a). This second form of mental representation (i.e., concept) is an ad hoc situated conceptualization constructed on the spot as an aggregation of the information from the various representational systems (e.g., linguistic, simulation) integrating it to support situated action in a predictive fashion (Barsalou, 2016a; Barsalou et al., 2008, 2018; Lebois et al., 2015). Concepts are highly flexible, resulting from the activation of conceptual knowledge unique to the particular circumstances in which they are created. This means that concepts have no fixed content that activates independently of context, but rather work as tools or skills to tackle the specifics of the situation in which they are constructed. As Connell and Lynott, (2014. p. 390) put it, "you can't represent the same concept twice." Hence, the study of people's mental representations becomes the study of people's skill to construct concepts dynamically in different situations and contexts (Barsalou, 2003).

The human conceptual system performs different operations that support all cognitive processes (for reviews, see Barsalou, 1999, 2012, 2016c). First, concepts are necessary for categorization. Categorization is the ability to identify individual units by assigning them a

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[25] Language is itself grounded in the modalities (e.g., Borghi et al., 2019) complicating, even more, the alleged distinction between the grounded and linguistic (distributional) systems in conceptual processing (see Davis & Yee, 2021).

[26] According to the situated conceptualization framework, conceptual knowledge contains information that includes the perceptual characteristics and motor affordances of a category, its relational structure to other categories (e.g., functions, goals), the internal states that accompany dealing with it (e.g., affect, mentalizing), and background information of the situation where the category was found (Barsalou, 1999, 2003). All this information is organized to solve the interface problem between the body (action) and the environment (Barsalou, 2003).

unit of conceptual knowledge. Through categorization, type-token relationships between an entity and a concept that are either true or false are established (i.e., propositions). Categorizations and propositions are not the objective of the conceptual system but rather serve to make inferences (Barsalou, 1999). The brain's inferential abilities appear to be a central element of its functioning, as increasing evidence and models suggest that its architecture is organized for prediction (see A. Clark, 2013; Hutchinson & Barrett, 2019). Moreover, concepts can be mixed and combined in myriad ways in relation to the context, giving us the ability to produce potentially infinite new concepts. This combinatorial ability works in tandem with the language system to go beyond our sensory experience and through which we constitute the concepts that make our socio-cultural realities (see Lupyan, 2016). More importantly, concepts support all sorts of offline and online cognitive processes. These include high-level offline processes such as planning, episodic memory, problem-solving, and socio-cognitive activities on the one hand, and online activity such as pattern completion and the identification of the motor affordances of objects, among many other processes (Barsalou, 1999, 2005, 2012). More essential for the purposes of this thesis, conceptual processes are at the centre of the construction of emotions (Barrett, 2006b; Barrett et al., 2014; Barrett, 2017a; Lebois et al., 2018; Wilson-Mendenhall et al., 2011; Wilson-Mendenhall, 2017; Wilson-Mendenhall & Barsalou, 2016). Through its various operations (e.g., categorization, inference) conceptual processes stand at the centre of all cognition as a domain-general system subject to all the biological and environmental constraints of our brains, bodies, and contexts (Barsalou, 2012).

Lastly, it is worth pointing out that concepts are not randomly constituted, but are instead constructed statistically, a fact which helps to address the puzzle of how concepts with no core still seem similar across people (see Barsalou, 2017a). Concepts that are more easily constructed reflect the effects of frequency, recency, and context (Barsalou, 2003, 2009, 2011). Lebois et al. (2015), for example, argue that concepts are constructed in a Bayesian manner, as a function of, on the one hand, information stored as conceptual knowledge from frequent and recent encounters with the category and, on the other hand, the information in the current context. A complementary account argues that because "we largely experience the same world" (Davis & Yee, 2021, p. 18), the statistical regularities we have encountered in our personal experience, as well as those of the current situation, allow people to construct concepts which overlap roughly, permitting "good enough" communication to occur

(Casasanto & Lupyan, 2015; Connell & Lynott, 2014; Ferreira et al., 2002; Yee & Thompson-Schill, 2016).

3.1.2. Language and situated simulation (LASS)

Barsalou et al. (2008) argue that concepts are mainly the results of the interaction of the simulation and language systems, among the various representational processes occurring in the brain. The language and situated simulation (LASS) theory is a hybrid approach to explaining the dynamics of representation; it holds that, in a situated conceptualization, both simulation and linguistic systems are immediately engaged in conceptual processing. However, in most situations, the language system will activate first, providing faster information about the content of the concept. The information from the linguistic system rests on shallow associations between words, forming a network that is computationally and metabolically cheap. This heuristic shortcuts the much deeper processing in the simulation (Connell, 2019; Santos et al., 2011). Importantly, knowledge in the language system is organized in a network that resembles the statistical regularities found in natural language, as described by distributional theories (e.g., Landauer & Dumais, 1997; Vigliocco et al., 2009). In this early stage of conceptual processing, a concept is only partially grounded in language[27], in that its referents temporarily are the words to which it is statistically related within the distributed network. Although shallow, the constituted concept can carry enough information to sort out a simple task that does not require deep processing.

In parallel to the foregoing processes, the simulation system activates a few seconds after the language system (e.g., Simmons et al., 2008) [28]. However, in the LASS, executive functioning focuses on the linguistic system until it "stops being useful" (Barsalou et al., 2008, p. 250), after which a multimodal simulation becomes more engaged, partially re-enacting the interaction with the category using stored perceptual, motor, interoceptive and

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[27] Again, language itself is grounded in action, interoception, and perception (Barsalou, 2016c), particularly, in the mouth (Borghi et al., 2019).

[28] There is evidence that conceptual processing uses the linguistic system first while simulation processes occur later. Santos et al. (2011) observed that the early words produced in word association and property generation tasks were linguistically related while the latter ones describe properties of the category or the situation. De Deyne and Storms (2008a) also observed that property, situation, and introspective features were produced more frequently in the latter responses of a word association task while taxonomic and lexical responses declined as the task progressed. Finally, on a neuroimaging study, Simmons et al. (2008) observed that both systems became active from the beginning of a 15-second property generation task, but that the language system dominated the first 7.5 seconds while the simulation system took charge in the second half of the task. Moreover, the LASS suggests that differences in task activate in different proportions and time scales the different representational systems involved in conceptual processing. For example, Wu and Barsalou (2009) observed differences between tasks where word associations produced less simulation-based responses than those participants asked to generate properties or use mental imagery. While simulations may activate slower, in most situations, they are the dominant form of conceptual processing. This will be important in chapter six.

other such forms of knowledge. This includes information about the properties, relations, and situations of a category, providing in-depth understanding and the tools for its manipulation. Moreover, the spreading activation of the linguistic associates of a category in its distributed network may also activate the corresponding simulation of other categories, compounding the dynamicity of the interaction between systems. Similarly, the elements of the simulation that go online, constitute their linguistic forms, which in turn activate even more words within the network. This ongoing process carries on recursively as simulation and linguistic systems go back and forth constituting different forms of information, cueing more linguistic forms and simulations, and producing the complex conceptual processing to support all other cognitive activities for engaging with the situation at hand.

It is worth highlighting that the constructs of the simulation and linguistic systems are intended to be understood as broad simplifications; they are spread throughout the brain and are dependent on an array of neurological systems that contribute to many other activities aside from conceptual processing (Barsalou et al., 2008). Moreover, these systems are interconnected, supporting each other in ways that researchers in this area are only beginning to understand (Connell, 2019; Connell & Lynott, 2013, 2014; Davis & Yee, 2021; Yee & Thompson-Schill, 2016). This complexity scales up, for example, when increasingly developed linguistic forms, such as phrases, sentences, narratives, and other forms of natural language usage in real-world interactions, are applied to the distinction between the simulation and the linguistic systems. Through these interactions between simulation and language, humans are able to construct concepts in flexible ways that far exceed the abilities of any other species on the planet. These ideas about the LASS serve as the theoretical and analytical backbone of the word association study in chapter six.

3.1.3. The brain as a situation processing architecture (BASPA)

Perhaps the most important aspect of Barsalou's model is the idea that concepts are never constructed in a way that is disconnected from the contexts in which they occur. Rather, they are constructed to support situated action (Barsalou, 2016b, 2019; Barsalou et al., 2018; Yeh & Barsalou, 2006). Conceptual knowledge of a category in the form of perceptual symbols includes information about the background (i.e., situation) where the object is experienced (see Barsalou, 2003, 2005, 2009, 2016a). When the brain constructs a concept, it uses this background conceptual knowledge to create an ad hoc concept tailored to the current situation[29], supporting the interface of the body and its goals (see Casasanto & Lupyan, 2015). The ad hoc construction of concepts in a situation is called a *situated conceptualization* (Barsalou 2003; 2009; 2016a)[30]. According to Barsalou et al. (2018), situated conceptualization is the brain's central processing function.

These authors argue that the processing of the structure of a situation is reflected in the brain's physical structure (i.e., BASPA; Barsalou et al., 2018). According to this hypothesis, the brain's architecture comprises two kinds of multimodal neural systems: systems that process situational elements and those that integrate these elements into more extensive arrangements around their co-occurrence (Barsalou et al., 2018, p. 2). The first of these neural systems stores conceptual knowledge and constructs concepts for the independent elements of a situation. When a person repeatedly experiences a situation, its co-occurring external and internal elements are stored in memory as conceptual knowledge of those independent elements. These elements are captured by particular neural networks, each of which provides a continuous stream of information about a specific kind of both external and internal element. The authors identify neural networks for external situational elements such as settings (e.g., classroom, pub), objects (e.g., scissors, apple), agents (e.g., friend, dog), physical actions (e.g., thrown, kneel), and physical outcomes (e.g., bake a pie, finish the essay), as well as internal elements including self-relevance (e.g., hospitality, elegance), motivation (e.g., curiosity, interest), affect (e.g., tiredness, excitement), and mentalizing (e.g., thinking, questioning) (Barsalou et al., 2018). Each of these networks is continuously constructing situated conceptualizations (i.e., concepts) for each of the independent elements of a situation (e.g., settings, objects, agents, affect) as a person moves through the world from situation to situation.

The authors also suggest a second kind of neural system that stores and processes conceptual knowledge about the many different relations between the external and internal elements in a situation. These systems produce situated conceptualizations that integrate the various information streams from the first system into a coherent totality (Barsalou et al., 2018). Different kinds of such situational integrators develop along with the different forms of

[29] Yeh and Barsalou (2007) define a situation as a "region of perceived space that surrounds a focal entity over some temporal duration, perceived from the subjective perspective of the agent" (p. 353)
[30] This new conceptualization is added to the population of similar instances stored in memory, becoming available for future use.

relational structures between the internal and external elements in a situation, including goal-directed action (e.g., eating, borrowing), causal chains (e.g., prompt, finish), and themes (e.g., kitchen items, musical instruments). Whichever relations are learned as situational integrators, these can later be used as tools for interpreting the environment, predicting potential events through inferences, and allowing for goal-directed interaction, among other things.

Notably, the BASPA scraps the distinction between concrete and abstract concepts. The authors introduce a more sophisticated taxonomy, one in which, on the one hand, some concepts refer to internal situational elements and some to external situational elements, and, on the other hand, some conceptualizations produce situational elements while others produce situational integrations (Barsalou et al., 2018). Although the first distinction between external and internal situational elements seems similar to the customary concrete/abstract division, the second element of categorization highlights how so-called concrete and abstract concepts include external and internal information. For example, the word 'couch' can refer to the concept for the external object in a situation (i.e., a piece of furniture). However, a 'couch' is also always part of a relational structure (e.g., sitting, lounging, hanging out) which integrates agents (e.g., friends), physical actions (e.g., laying down), objects (e.g., cushions), settings (e.g., living rooms), affect (e.g., pleasure), goals (e.g., bonding), motivation (e.g., to relax), and so on. More importantly, so-called abstract concepts (e.g., freedom, feud, truth, criticism) work for the most part as situational integrators - relational structures that hold together external and internal situational elements.

The BASPA provides an account of the mechanisms through which concepts carry with them information about their properties and the situations in which they are embedded. Concepts are never constructed in a vacuum, but rather they are always in a relational structure with other concepts that co-occur in time. The analytical framework through which I describe the elements of situations in chapters five and seven is based on the BASPA.

I now move to a constructionist description of emotions, a theoretical framework that has taken much inspiration from Barsalou's ideas, to explain the mechanisms through which emotions are constituted in situations.

3.2. A constructionist view of emotion

According to the constructionist view of emotions[31], emotions are emergent mental phenomena that result from the dynamic interface between domain-general processes in the brain and a body embedded in a socio-cultural context (Barrett, 2006b, 2017a; Boddice, 2018; Gendron et al., 2020). These domain-general processes are the product of our evolutionary history and are generally involved in all cognitive affairs, such as memory, perception, and reasoning (Barrett, 2009, 2013). In the next section, I go through the domain-general ingredients that make an emotion, exploring how these interact to constitute the situated experience of emotion and its practice in the sociocultural world.

3.2.1. Domain general processes

One of the brain's primary functions is to efficiently distribute resources to the body by anticipating its necessities, a process known as *allostasis* (Sterling, 2012). According to this functional model of the brain, it is constantly adjusting its physiological systems, such as the endocrine and autonomic nervous systems, to promote the individual's survival and reproduction. To maintain allostasis efficiently, the brain is not merely reacting to signals coming from the body, but rather producing an internal simulation of what is going on inside to forestall whatever needs might arise and prepare for acting upon these (Barrett, 2017c). The representation of this continuously running internal model is called *interoception,* which, when made available to consciousness, is in part experienced as feelings of valence and arousal, or what has traditionally been called affect (Barrett, 2017a, 2017c; Barrett & Bliss-Moreau, 2009; Barrett & Simmons, 2015; Russell & Barrett, 1999). Interoception is a domain-general process involved in every aspect of cognition (Barrett, 2017c; Barrett & Bliss-Moreau, 2009, Barrett & Simmons, 2015) and constitutes one of the core ingredients of

[31] Barrett (2006b) introduced the most recent iterations of construction models of emotion in 2006 as a psychological model of emotions called the conceptual act theory. The theory has matured since its introduction, having incorporated into its repertoire ideas and concepts from neuroconstruction, social constructionism, cultural constructionism, and rational constructionism on the one hand and various other insights from neuroscience, cognitive science, philosophy of the mind, and the result of empirical studies on the other (Barrett, 2012, 2013; Barrett et al., 2007, 2011; Barrett & Russell, 2014; Barrett & Satpute, 2013; Lindquist et al., 2012; Lindquist & Barrett, 2012; Siegel et al., 2018; Wilson-Mendenhall et al., 2011). The theory is substantiated in its strong commitment to grounded theories of knowledge and in particular the situated conceptualization framework (e.g., Barsalou, 2003, 2005, 2009, 2016a) resulting in a series of collaborations between Barrett, Barsalou and many others within the same paradigm of cognitive science (Barrett et al., 2014; Lebois et al., 2018; Wilson-Mendenhall et al., 2011). More recently, Barrett and associates have articulated the situated conceptualization framework within the predictive coding accounts (e.g., Clark, 2013; Hutchinson & Barrett, 2019) of brain architecture and functioning (e.g., Barrett, 2017c). These models are then works-in-progress, producing various empirically testable hypotheses that today multiple research groups worldwide are trying to tackle. The central hypothesis of this thesis, that awe is a culturally constructed folk category central to the culture of science communication, stems from the insight of these theories.

the construction of emotions (Barrett et al., 2014; Wilson-Mendenhall & Barsalou, 2016) and more broadly, of all situated experience (Barsalou et al., 2018).

Other domain-general processes critical in emotion are *statistical learning, selective attention*[32] and more importantly, *language* (Barrett et al., 2007; Hoemann et al., 2019; Lindquist et al., 2015). Emotion categories do not have concrete regularities in the world that allow inferring their properties and encoding them as conceptual knowledge. Emotion categories such as anger, joy, and love are what philosophers call *ontologically subjective*, that is, they are objects which acquire their realness and functions based on the social meanings that people collectively assign to them, meaning that they only exist in *social reality* (i.e., culture) as categories (Barrett, 2012; Searle, 1995, 1999). Language bootstraps conceptual knowledge, working as an important statistical anchor in its redundancy through which emotion category knowledge can be learned and stored (Barrett et al., 2007). Preverbal infants use their statistical learning tools to pick up regularities in speech patterns and word sounds; in the case of emotions, emotion words fix knowledge for emotion categories (Atzil et al., 2018; Barrett et al., 2007, 2014; Hoemann et al., 2019). Once the child has learned an emotion word (e.g., 'angry', 'happy') co-occurring with different elements and relations in situations (e.g., throwing a toy, smiling) the infant begins to aggregate a population of exemplars to the conceptual knowledge for the emotion category the word stands for. Importantly, emotion categories such as joy, sadness, disgust, and in our case, awe, are conceptual categories, meaning that their function or goal is what makes one occurrence similar to another (Barrett, 2012; Hoemann & Barrett, 2019). However, there is no one-to-one equivalence between an emotion category and a function (Hoemann et al., 2019; Lebois et al., 2019; Wilson-Mendenhall et al., 2011). An emotion can have many functions, in relation to the specific contexts where it is utilized. As Hoemann et al. (2019) put it in their discussion of anger:[33]

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[32] Newborns have almost no concepts, so their brain is, for the most part, receiving information through the senses (Atzil et al., 2018). Our evolutionary heritage equipped humans with a brain made to attend to the statistical regularities in the environment and extract knowledge from it (Atzil et al., 2018; Xu & Kushnir, 2013). This powerful *statistical learning* mechanism continuously encodes conceptual knowledge as the brain takes in more sensory input from experience. However, not all sensory information is encoded equally. Humans also have a set of *attentional skills* that allow for selecting the most important aspects of the sensory information and structure conceptual knowledge in ways that make its later use more efficient (Wilson-Mendenhall & Barsalou, 2016). As selective attention focuses on a category throughout various experiences, a unique population of mental representations forms in memory in the form of conceptual knowledge for that element of experience (Barrett et al., 2014; Barsalou, 1999). Attention mechanisms also focus and encode certain elements, which could be from the world, the body, or the mind, more than others in relation to the situational demands.

[33] A version of this paragraph appears in (Silva Luna & Bering, 2020, p. 5)

[. . .] instances of anger can be associated with the goal to overcome an obstacle [particularly when the obstacle is another person], to protect against a threat, to signal social dominance or appear powerful, to affiliate and repair social connections, to enhance performance to win a competition or a negotiation, or to enhance self-insight (p. 1833).

An emotion word can refer to a multiplicity of goals in relation to the many other elements present in a situation[34]. Clusters form around a frequent set of situations with similar goals to form emotion types[35] (Boiger et al., 2018). These types create an illusion of coherence and stable conceptual knowledge when, in reality, emotions have no core set of properties (Barrett, 2006b). Moreover, once a population of conceptual knowledge becomes established around the emotion word, it is continuously updated, growing, and changing throughout a person's lifetime as a result of every interaction and experience in which the category is involved. These experiences can be direct or vicarious, occurring through social interactions or the result of past reconstructions and future projections (Barrett, 2013, 2017a).[36]

The last important domain-general process in the construction of emotion is the aforementioned *conceptual system*. Using emotion conceptual knowledge, brains create dynamic and flexible ad hoc emotion concepts in situated conceptualizations (i.e., predictions) that provide information beyond that presented by the immediate sensory inputs to guide situated action (Barrett et al., 2014; Barsalou, 2003; Hoemann & Barrett, 2019;

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[34] The conceptual flexibility assumed in the theory (e.g., ad hoc concepts) means that the goals are also changing with the situations in which the emotion occurs (Wilson-Mendenhall et al., 2011; Wilson-Mendenhall & Barsalou, 2016).

[35] Types can result from the frequency and recency with which people encounter elements, relations, and goals in situations, which dynamically establish which aspects of emotion conceptual knowledge become activated (Barsalou, 2003). The construction of types could explain the degree of similarities in responses observed in emotion research that has led observers to incorrectly believe in the existence of prototypes, schemas, or any other form of core features (i.e., essences) of emotion categories (Barrett et al., 2014, 2019). The type of statistical structures that emerge from the construction of types (e.g., family resemblances) is one reason for emotion coherence and communication (Lebois et al., 2015; Wilson-Mendenhall et al., 2011).

[36] Recent versions of the constructionist view of emotion argue that a brain is always constructing an internal model of the body and the environment by continually issuing an avalanche of top-down predictions signals simultaneously and in cascades throughout the whole brain that compete probabilistically as the hypothesis that is tested against the sensory input that is coming from inside and outside the body, filtering information, preparing the body for action, and guiding attention, among other things (Barrett, 2017a, 2017c; Barrett et al., 2014; Barrett & Simmons, 2015). The brain takes the sensory input of a situation and compares it to previous similar situations in the form of predictions in an effort to anticipate the future. These predictions anticipate the external and internal milieu, filtering out the information that comes in through the senses while mobilizing resources for the body to act and minimize the body's metabolic costs (see Barrett, 2017a, 2017c). When the sensory input does not match the prediction, a prediction error is issued, updating the brain's content by fine-tuning it to improve performance in potential future predictions. Prediction error is *learning*, and the brain is continually going from issuing predictions, testing them against the incoming sensory input, and adjusting the next iteration when prediction error occurs. The brain constitutes its internal model of the world in the ongoing loop between prediction and prediction error, allowing for the efficient metabolic functioning of the brain through the use of experience, to anticipate the allostatic needs of a body in a dynamically changing context (Barrett, 2017a, 2017c; Hutchinson & Barrett, 2019). This predictive coding account of the theory of constructed emotion presented in Barrett (2017c), Chanes and Barrett (2016) and other works, elaborates much more on the neurophysiological mechanisms through which emotions are created in brain networks. Here I present the version at the psychological level of analysis elaborated in Barrett et al. (2014) and other works based on the situated conceptualization framework.

Wilson-Mendenhall, 2017). Once an emotion concept has been created, inferences and predictions about the properties, elements, and relations of a situation are made, first interpreting their contents through categorization, and then re-enacting perceptual and motor representations, foretelling the immediate future, and summoning resources in ways tailored to the goals of the situation (Barrett, 2017a; Barrett et al., 2014). Situated conceptualizations are how the brain interprets a situation through an emotion category (e.g., sad funeral, joyful bike ride, angry political speech) giving emotion meaning to the sensory inputs from within and outside the body in a process that is automatic, dynamic, continuous, ongoing, enactive, mostly unconscious, and thoroughly grounded (Barrett et al., 2014; Wilson-Mendenhall, 2017; Wilson-Mendenhall & Barsalou, 2016).

Affect, statistical learning, attention, language, and conceptual processing are accompanied by other domain-general systems, such as the behavioural adaptations of fight or flight or the startle reflexes, to constitute emotions (Barrett et al., 2014). In addition, these domain-general processes are involved in all other cognitive activities, including perception, planning, and the construction of the self (Barrett, 2009; Barrett & Satpute, 2013; Hutchinson & Barrett, 2019).

3.2.2. The construction of emotion in biology and culture

People construct an emotion episode when their brains produce a situated conceptualization in response to – and to predict – a changing element of an unfolding situation using conceptual knowledge of an emotion category (Barrett, 2006b, 2017a; Barrett et al., 2014). Emotions work for the most part as situational integrators, combining the elements of a situation within a relational structure to achieve a particular goal (Barsalou et al., 2018; Wilson-Mendenhall et al., 2011). This means that the resulting emotion concept integrates external and internal elements into a unified totality, producing a series of inferences about the situation, recruiting cognitive, motor, physiological, and attentional resources to prepare and drive a person to act (i.e., it is integrative, predictive, enactive, embodied, and functional). The emotion concept is a partial re-enactment of the population of instances tailored to the situation created in a Bayesian manner, reflecting the availability of knowledge from prior experiences with the emotion category in relation to the relevant information about the present context (Barrett, 2017c; Barsalou, 2011, 2016a)[37]. Many times, the concept is constructed in response to and to predict a change in the body's internal milieu (e.g., as an interpretation to increased arousal). However, it can also occur as a result of a change or prediction of the unfolding of any of the internal and external elements of a situation and their relations, or the inferences made from these elements (Barrett, 2006b, 2017a; Barrett et al., 2014). Emotion concepts are particularly good at mobilising physiological resources, leading to the strong interoceptive and affective changes traditionally associated with emotions (e.g., sympathetic and parasympathetic changes). Affect, however, is only one of the many accompanying and coordinating elements in a situated conceptualization.

Importantly, emotion concepts guide action, and this is manifested in expressions, behaviours, habits, rituals, communication, and other forms of practice (Gendron, et al., 2020; see also Scheer, 2012). The goal of these actions, whether social coordination, conceptual synchrony, product production, identity reinforcement, or any of the many things that emotions do, changes an aspect of the world. This can be something in the material world (e.g., a smile, an insult, writing a poem on a piece of paper, cooking your favourite meal), or someone's brain wiring. This last includes the brain wiring of the person experiencing the emotion, meaning that every new situated conceptualization is somewhat stored in memory, becoming part of the conceptual knowledge from which potential future concepts can be constructed. Finally, because of the flexibility of conceptual processes, emotion concepts are always being combined and recombined in numerous ways with other concepts on-the-spot, creating an infinite collection of potentially new conceptual combinations for emotions (Barsalou, 1999; Hoemann et al., 2017). Together, from the moment that an emotion concept is constructed in a situated conceptualization, integration, inference, mobilization, action, combination, and all other processes occur together to make out the totality of an emotional episode.

More importantly, the emotion categories (e.g., anger, love, fear) around which conceptual knowledge accumulates and from which people construct their emotions are historically and culturally contingent (Abu-Lughod, 1988; Averill, 1980; Barrett, 2017a; Boddice, 2018; Lutz, 1988). The emotion categories people use today have multiple histories shaped by the linguistic, economic, political, technological, social, and moral shifts of the cultures where

[37] A version of these sentences appears in (Silva Luna & Bering, 2020, p. 6)

these emotions circulate (Boddice, 2018; 2019; 2020b)[38]. As a result of these histories, each culture has landed today on its own particular set of categories to describe affective content[39].

More importantly, although the categories through which emotions are constituted are culturally relative, cultures create the conditions for standardising cultural experiences. Cultures foster regularities in the situational environments from which people learn the conceptual knowledge for an emotion category, following predictable patterns that can be studied systematically (De Leersnyder et al., 2015a; Gendron et al., 2020; Mesquita et al., 2017). For example, cultures foster situations whereby people experience more emotions that are consistent with the culture's mandates – the values, norms, beliefs, goals, and worldviews shared within a cultural space and that help people navigate the social world around common intentions (Mesquita et al., 2015, 2017)[40]. Other similar cultural standardisation and conventionalisation processes lead to particular emotion types; types that are promoted in their practices and products of a culture (Boiger et al., 2013) in the form of social representations (O'Connor, 2016)[41]. Additionally, people from a culture seek out situations that promote the emotion types of their culture (Tsai, 2007). The repeated exposure in situations to social representations of culturally normative emotion types leads to a certain degree of convergence of people's emotion knowledge within a cultural space (Barrett, 2017a; De Leersnyder, 2017; De Leersnyder et al., 2011).

From the time we are born, people are enculturated and acculturated to the different emotion types present in the cultures they navigate. As children learn emotion words from listening to their caretakers, they begin to associate situations with no distinct observable similarities to an emotion category around some relevant goal (Hoemann et al., 2019). Being immersed in their culture, this social learning is reinforced and expanded through the interaction with the many social representations of these emotions in the behaviours, expressions, habits, traditions, rituals, stories, and other forms of emotion practices and products to which the child increasingly has access as they develop (Gendron & Barrett, 2018). This process of

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[38] The topic of the history of emotion categories is better described in the next chapter.

[39] It is important to remember that although in the Western, industrialized world we have landed on the category emotion to describe a certain kind of affectively strong phenomena, many cultures around the world don't have categories that correspond to what we mean by 'emotion' (see Russell, 1991). This doesn't mean that they don't have affective experiences but rather to say that the categories through which they demarcate what counts as 'emotion' or not is different from our categorization.

[40] This sentence appears in (Silva Luna & Bering, 2020, p. 5)

[41] Social representation refers to the stereotypical knowledge of a category that members of a cultural space share to a certain extent and which are represented in-the-world. As O'Connor (2016, p. 4) writes, "social representations are conceived as residing across rather than within individual minds, inhabiting the 'between-space' where individual and society connect." They are related yet different from mental representations which refer to the individual's ad hoc construction of a category.

emotion enculturation does not stop in childhood but rather continues as acculturation through a person's life (de Leersnyder, 2017). By adulthood, individuals have acquired a large population of diverse instances for each of the emotion categories that are important to the cultures in which they participate (Mesquita et al., 2016). Emotions can then be thought of as skills people develop to fit in their cultures (e.g., De Leersnyder et al., 2015b). Emotion learning as category learning and skill development means that people can potentially learn any new emotion at any stage of their lives while also being able to change the content of the conceptual knowledge for a particular emotion category through new experiences (Barrett, 2017a, Gendron & Barrett, 2018). However, the effectiveness of emotion acculturation is limited by the previous conceptual knowledge and how frequently they are exposed to the new emotion types, which relies on how important these emotion types are to the sociocultural context that the person navigates (Gendron & Barrett, 2018; Mesquita et al., 2016). Enculturation and acculturation processes mean emotions are not innate but rather learned (Barrett, 2017a; Hoemann et al., 2019; Lebois et al., 2018). More importantly, this means that recurrent exposure to an emotion category results in an increasing level of skill with that emotion (i.e., emotional expertise) (Hoemann, Nielson et al., 2020).

It is worth highlighting, however, that emotions are not pluripotent or random. Foremost, emotions are constrained by the biological realities of the brain's domain-general features (Barrett, 2017a). Domain-general features are universal and establish the "emotional potential" from which all emotions are constituted (Mesquita et al., 2015, p. 542). Nonetheless, they are inscribed within the normal energetic and physical limitations of our bodies. This may also lead to convergent cultural evolution (Richerson & Boyd, 2005), in which categories around universal elements of experience (e.g., affect, eating, dying) lead to a certain degree of similarity in people's emotional knowledge (Gendron et al., 2020). Similarly, cross-cultural dynamics related to geographic proximity such as trade, migration, and translation, may lead to different forms of borrowing which result in the convergence of emotion categories across cultural spaces (Jackson et al., 2019).

I believe that the construction description of emotions is to date the best multi-disciplinary explanation about their nature. This represents a paradigm shift in our understanding of how emotions work, bridging the gap between the individual and sociocultural contexts in which they are represented. More importantly, the theory supports my understanding of awe as historically contingent and culturally relative for English speakers and to the culture of science communication. In the next section, therefore, I present an analytical framework suited to my subsequent studies on this complex emotion.

3.3. An analytical framework for studying constructed emotions

In most instances, emotions work as situational integrators that combine the different elements of a situation through a relational structure around a specific goal (Barrett et al., 2014; Lebois et al., 2018; Wilson-Mendenhall et al., 2011). An emotion can then be described in terms of the different co-occurring external and internal situational elements that define its form and function. Internal situational elements refer to the body and the mind, which include *affect*, *motivation*, *self-relevance*, *mentalizing,* and so forth. Similarly, external situational elements include elements of the immediate physical and social context where the person is situated including the *settings*, *agents*, *actions*, and *objects* in a situation (Barsalou et al., 2018). Together the different elements provide the form that an emotion takes. More importantly, in their relational structure, the elements direct the body towards a particular situated goal or outcome, giving the emotion its functional status. This might include situated movement, communicating a state, assigning value to something, influencing others, constituting an identity, or any of the many other functions that an emotion does (Barrett, 2017a; Barrett et al., 2014; Gendron & Barrett, 2018).

Barsalou et al. (2018) recognize that their taxonomy of the elements and functions of a situation is not comprehensive and can be further elaborated. I add to their taxonomy using other work that taxonomizes situations, particularly that which has investigated the elements that could be important during an emotion. Some componential appraisal models of emotion have developed a highly sophisticated description of the situational elements of emotional events (e.g., Fontaine et al., 2013; Moors, 2010b; Scherer, 1984; Stein & Hernandez, 2007). Moreover, various taxonomies coming from linguistics, semantics, cognitive science, and other subject areas, also describe different elements of a situation. For example, schemes evaluating the semantic content of words through so-called ontologies have listed a variety of objects and properties, such as people, living things, social organizations, social artefacts, buildings, locations, time, manner, physical states, and quantity that can be included as external elements of a situation (e.g., Cree & McRae, 2003; De Deyne & Storms, 2008a; McRae et al., 2005; Wu & Barsalou, 2009). I take some of the elements described in these models to complement the external and internal situational elements and functions proposed by Barsalou et al. (2018) and offer the following taxonomy:

1) Actions
    a. Expressions (e.g., facial expressions)
    b. Behaviour (e.g., body movement)
    c. Approach/Avoid
2) Motivations
3) Interoceptions
    a. Affect
        i. Valence
        ii. Arousal
    b. Bodily sensations
4) Mental States
    a. Mentalizing
    b. Self-Relevance
        i. Identities
        ii. Beliefs
        iii. Values
        iv. Preferences
        v. Norms
    c. Evaluations/Appraisals
    d. Emotions
    e. Moods
5) Settings
    a. Location
    b. Time
6) Events
7) Objects
    a. Cultural artefact
    b. Non-cultural artefact
8) Agents
    a. Human
    b. Non-human agent

9) Social environment
10) Other's actions
    a. Behaviours
    b. Expressions
11) Outcomes/Goals

Although incomplete, this taxonomy of situational elements represents my attempt to systematize the forms and functions that make up a description of an emotion. It includes four internal and six external elements of a situation that define its form, plus a category for the outcome or goal through which the function of the emotion is defined. The categories of analysis used in chapters five and seven are sketched from this taxonomy.

Moreover, while I assume that emotions have no essentialized types and are always ad hoc constructions, they tend to present certain regularities, which I define as emotion types (Mesquita et al., 2016, 2017). Emotion types are the conventionalized and standardized cultural versions of emotion (i.e., social representations), made up of recurring forms around a particular function and which are represented with a certain regularity in a cultural space. Emotion types can also be thought of as those shared social meanings that constitute the basis of people's emotion knowledge in a culture. For the case of awe, settings such as the outdoors (e.g., Bai et al., 2017), or outer space (e.g., Yaden et al., 2016), expressions such as the jaw-dropped mouth (Shiota et al., 2003), motivations such as altruism (e.g., Piff et al., 2015), behaviours such as freezing (e.g., Joye & Dewitte, 2016), interoceptions such as positive affect (e.g., Shiota et al., 2007), appraisals of vastness and descriptions of the self, such as those of smallness and connectedness (e.g., Yaden et al., 2019), are elements of the types of awe that are common in the culture of English speakers. However, while common, these are but stereotypes that capture only a subset of the totality of ways in which an emotion can be represented. Importantly, the types for an emotion category will vary across cultures and subcultures, as a function of their cultural mandates.

I also assume that a situational integrator such as an emotion not only carries information about the elements that make up an episode but also about the relationships between these elements (Barsalou, 2019; Barsalou et al., 2018). These structures could be described in terms of narratives, scripts, schemas, frames, scenarios, action cycles, themes or any other sort of framework that realizes the relational structure of the elements in a situated conceptualization (e.g., Bamberg, 1997; Barsalou, 2019; Davis, et al., 2020; Russell, 1991). These frameworks are tied to larger formations, such as discourses or aesthetics, which further cement the conventionalized ways in which the different elements of an emotion and their functions are represented (Lutz & Abu-Lughod, 1990). For example, narratives for awe such as those of the lone male wanderer who climbs atop a mountain and experiences awe at the sight of a vast view, feeling an overpowering positive affect – a story staunchly caught within discourses of the natural sublime (see the next chapter) – provide the relational frameworks that hold the elements of emotion together around the goals of transcendence and changing one's mind. These relational structures not only establish the association through which an emotion is constituted from different elements of situations, but are also the framework through which emotions are constitutive of the representation of objects, agents, behaviours, identities, beliefs, values and all other elements encountered in situations – a productive capacity that has been highlighted by many anthropologists, critical theorists, and historians (Ahmed, 2004; Boddice, 2018; Boddice & M. Smith, 2020; Illouz, 2008; Lutz & Abu-Lughod, 1990; Harding & Pribram, 2002).

Lastly, I assume that as people spend more time within a particular cultural space, they will increasingly accumulate more experiences (i.e., emotion knowledge) developing the skills for the emotion types (their elements and relational structures) prevalent in that culture. As they increasingly acculturate into the emotions of a cultural space, they become more skilled in representing those particular conventions (i.e., social representations), moving along a continuum of expertise for those emotion types. Increases in skill on culturally specific emotion types will manifest in increasing efficiency, control, and ability to mentally represent this emotion, among other abilities (Hoemann, Nielson et al., 2020).

The taxonomy for the elements of an emotion derived from the application of the situated conceptualization and the ideas derived from theories related to the constructionist view of emotions serves as an analytical framework through which to study emotions in situations and across cultural contexts. This framework will be utilized throughout the studies in the upcoming chapters. Now, I move away from descriptions of science communication as an activity of transfer of information and conceptualize it instead as a cultural space.

3.4. Science communication as cultural space

Science communication is a culture[42]. The people in this culture share, to a certain extent, similar kinds of knowledges from which they can construct a set of analogous representations in-the-head (e.g., perceptions, norms, beliefs, values, expectations, memories) through concepts, and representations in-the-world (e.g., written words, sounds, rituals, expressions, images, poems) through various forms of practice and the production of different artefacts (Gendron et al., 2020)[43]. Broks' (2006) spatial metaphor can be used to describe science communication as the cultural space where people (e.g., scientists, science communicators, science enthusiasts, non-scientists) share a specific set of social meanings related to science. Those social representations related to science, however, are similar but not the same as the academic scientific knowledge used in science classrooms, conferences, papers, or other such spaces corresponding to other cultures such as science education and laboratory science. For example, the metaphors that are used to describe genes as maps, books, and blueprints are common in science communication, while scientists use other forms of representation when they talk amongst themselves to refer to the same topic (e.g., nucleotides, codons, and amino acid sequences) (Hellsten et al., 2008). These kinds of differences between the popular and academic scientific knowledge shared in science communication spaces result from contingent socio-historical processes that have led to diverging forms of social representation between the different cultures where science is the topic. However, while distinct, these cultural spaces are in direct and overlapping contact with each other, with boundaries that are both arbitrary and leaky, and bridges and trading zones where meanings flow from one space to the next (Broks, 2006).

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[42] Definitions of culture abound. For example, in the 1952 monograph *Culture: A Critical Review of Concepts and Definition*s, Kroeber and Kluckhohn (1952) do an extensive review of the literature on culture citing more than 100 authors including Freud, Parsons, Kant, Levi-Strauss, Wundt, and Mead. I define culture as the mental representations (e.g., knowledge, beliefs, values) and their manifestation in external representations (e.g., behaviours, products, practices), "shared by a group and acquired by new generations through social learning" (Gendron, Barrett, Mesquita, 2020, p. 188). The broad definition presented here bridges the gap between competing definitions of culture as in-the-head (in the mind) and those of culture in-the-world (in objects and practices) (e.g., Gendron, 2017; Jahoda, 2012). Cultures establish a set of preferred and dominant social meanings, conventions, or stereotypes, which are the result of social dynamics, environmental pressures, historical contingencies, and the constraints set by our biology, among other things (Barrett, 2017a; Mesquita et al., 2017; for parallels from other disciplines see Fiske, 2011, S. Hall, 2006). From birth, a person is continuously interacting with these social meanings, a process that wires the brain into a particular kind of cultural artefact, moulding it to represent a person's embodied experience and reproducing it to transmit it to future generations (Barrett, 2017a; Gendron et al., 2020).

[43] Culture is defined here as a transient phenomenon. In the same way that concepts are situated and dynamically constituted as a function of a person's experience and the affordances of a situation, culture is always assembled ad hoc the moment when those shared meanings are activated and disassembled the moment when the situation stops being about the culture of science communication (see Davies, 2018). This means that culture is not static, but it is always being created anew at the moment.

Moreover, the set of meanings that correspond to the culture of science communication go beyond its distinct set of social meanings related to scientific knowledge (Davies & Horst, 2016). The set of representations that circulate within this culture also includes social meanings for non-scientific content such as values, norms, beliefs, and other forms of social representations, which regulate the functioning of its practices and products. Notably, the social meanings in the culture of science communication are also constituted in bodily sensations and mental circumstances, something which can be referred to as embodied states (Davies & Horst, 2016). Beliefs, norms, identities, interests, and more importantly for this thesis, emotions, circulate widely within the meaning economy of the culture of science communication. Importantly, not only does the culture of science communication, as all other cultures, assign particular social meanings to emotion categories, but these meanings are also constitutive of the different forms of scientific and non-scientific knowledge in circulation within this space's semantic economy. Considering that affect is a domain-general process which is better thought of as a ubiquitous aspect of all mental processes (Gendron et al., 2020; Lebrecht et al., 2012), it is then important to consider how categories that are closely entwined with affect (e.g., emotions, moods, arousal states) permeate all other representations within this space. Affective categories such as emotions can then be described as particles in the constitution of the many other social meanings in this space represented in its practices and products (see Ahmed, 2004; Harding & Pribram, 2002; Illouz 2008, Cabañas & Illouz, 2019).

The science communication event is a cross-cultural moment where the social meanings of science communication are communicated (Aikenhead, 2001). Communication is not then just an act of transmitting information between a sender and a receiver, as in the transmission paradigm, but rather it is the ecosystem through which people produce, consume, regulate, and construct these shared meanings within the situations provided at the science communication event (Davies & Horst, 2016; see S. Hall et al., 2013). Whether it is reading a science magazine at home, visiting a science museum, retweeting a science tweet, or talking with friends about a scientific topic, people are continuously constructing meanings as a function of the specifics of the situation and the knowledge repertoire they bring from a lifetime of experiences, what Aikenhead (1996) calls their *lifeworld culture*. At this cross-cultural event, a negotiation occurs between a person's baggage of lifeworld cultural experiences and the social representations present at that specific science communication event. The construction of the preferred or dominant set of social meanings of science communication is then a function of the distance between a person's lifeworld culture, the social representations at the science communication event, and the idiosyncrasies of the day[44]. Whereas people closer to the cultural space tend to construct congruent meanings at the event, people farther apart will give meaning in different or even discordant ways, potentially feeling alienated from this cultural space (Aikenhead, 1996). These are nonetheless not straightforward processes but rather multi-directional, highly contextual, complex, performative, and interpretative (Davies & Horst, 2016), all of which involve a heterogeneous ecosystem of agents and objects that come together at the science communication event (see Davies, 2018).

However, the more time spent in the culture of science communication, the more they acquire the representational skills and adopt the social meanings of this space. People are continuously moving through the continuum of expertise for the different social meanings present in these spaces. This includes not just the popular scientific knowledge at the centre of this space, but also the values, norms, goals, worldviews, and all other cultural mandates that regulate it, among the different types of knowledge. Most importantly, with time, people increase their skills in the affective categories (e.g., emotions, moods) that are central to this culture. People learn and get better at representing wonder, curiosity, excitement, surprise, awe, and other such normative emotion categories that are valued in science communication.

As they develop their skills in these emotions and their particular types, they also become better at representing the many social meanings tethered to these. For example, they slowly form identities that give them a sense of belonging to the space (Davies & Horst, 2016). Identities around science communication such as the science enthusiast, the amateur scientist, the supporter, the science museumgoer, the sceptic, and the rationalist are constructed in relation to people's particular experiences in these science communication spaces, slowly becoming an intrinsic part of their lifeworld culture. Emotions such as wonder, curiosity, marvel, and awe are co-constitutive of these identities giving affective tones to the feelings of belonging that comes with identifying with a particular social group. This is just an example

[44] A myriad of factors, from the amount of sleep a person had the night before, to the structure of feeling of the day (R. Williams, 2009), can contribute to people's conceptualization of a science communication situation. An element of randomness is always at play (see Barrett, 2017a).

of how the many social meanings in this cultural space (e.g., objects, agents, values, ideas, beliefs) are entwined in deep networks of signification with emotions – networks through which people construct their experience and give shape to this cultural space.

Importantly, I conceptualise science communication as not one but as a multiplicity or mosaic of subcultures[45] (see Aikenhead, 1996; 2001). First, it is important to highlight that science communication is part of a larger cultural matrix, which includes cultural spaces such as the culture of mass media, the culture of museums, the culture of journalism, global western culture, capitalist culture etc. Moreover, science communication can be disaggregated into various types of subcultural units around issues such as those around nationality (e.g., the subculture of Aotearoa New Zealand), language (e.g., the subculture of science communication in Spanish), scientific discipline (e.g., the subculture of astronomy science communicators) or professional practice (e.g., the subculture of science journalists), and which can be further disaggregated into increasingly smaller subcultural intersectional units (e.g., the subculture of biomedical research journalist in Brazil, the subculture of the Manchester 2015 Science Festival organisers, the subculture of Vietnamese astronomy podcast enthusiasts, etc.). The people who participate in all these subcultural spaces share to a certain extent a set of social meanings that band them together under the large umbrella of the culture of science communication; the culture of science communication is a global culture. However, they will have their own local shared meanings that are unique to their specific sociocultural and historical idiosyncrasies.

While each of the many subcultures of science communication around the world have their unique forms of representation, an aggregation of these into broad subcultural clusters can be made around the dimension of cultural mandates. As described in the previous chapter, these broad subcultures can be described in terms of the dominant three-model framework of science communication (i.e., deficit, dialogue, participation) (see Bucchi, 2008; Metcalfe, 2019) and the different values, beliefs, and worldviews (i.e., hierarchical or democratic) that each of these models represent (e.g., Hilgartner, 1990). For example, Perrault (2013) identifies two critical sets of mandates in science communication the Public Appreciation of

[45] While what counts as a "subculture" is perhaps a matter of case-by-case considerations (e.g., Oyserman, 2017)[45], they can generally be described as smaller groups of people in relation to a larger cultural space, which can be grouped by aspects such as shared identity (e.g., political scientists), geographical location (e.g., people in Aotearoa New Zealand), relational ties (e.g., family), or any other unit in which two or more people share a series of unique meanings between them.

Science and Technology (PAST) and the Critical Understanding of Science in Public (CUSP). The PAST's cultural mandates are tied to ontological and epistemological commitments such as naïve realism, instrumental rationality, positivism, and objectivism, which put it ideologically in the camp of scientism. By contrast, the CUSP describes scientific knowledge as tentative, theory-laden, and deeply embedded in social and cultural systems, values and norms akin to scepticism, critical engagement, and epistemic modesty. These two frameworks can be largely described as two subcultures within the deficit to participation framework. The PAST can be associated with deficit-style science communication while dialogic and participatory practices move toward the CUSP. Similar descriptions of the different cultural mandates and worldviews in science communication around the deficit, dialogue, and participatory models can be found in the work of other authors (e.g., Bucchi, 2008; Metcalfe, 2019).

Other authors however propose taxonomies that complexify this simplistic dichotomy between deficit-style top-down science communication and bottom-up participatory practices by identifying other dimensions through which the mandates and worldviews in science communication practices can be described. Priest (2013, 2018) identifies most science communication practices as standing in a sort of continuum of either strategic or democratic goals. Strategic practices refer to those made with the intentions to influence a particular self-interested outcome (e.g., a PR campaign to get people to consume more eggs), while democratic communication is oriented towards giving people the tools to engage in the techno-societies they inhabit (e.g., dietary labels on food packages). While there is a degree of concordance between the deficit model and strategic communications, and the same between participatory and democratic communications, Priest (2013, 2018) argues that this is not necessarily the case in all situations. Democratic ideals can have a degree of top-downness while the same can be said about bottom-up strategic goals. This is complexified in the author's description of all science communication practices as being both strategic and democratic (Priest, 2018). This distinction between strategic and democratic mandates in science communications suggests that rather than contrasting hierarchical and egalitarian values, beliefs, and norms, the cultural mandates behind communicative practices are much more localized within the cultural systems of the institutions, government, and other forms of collective organization that practice science communication. Importantly, Priest (2018) identifies other potential mandates of science communication such as those of economic or entertainment goals that could serve as potential dimensions for analysis.

Following this lead, Davies (2021) empirically identifies six different cultural mandates derived from interviews with researchers. The instrumental, promotional, accountability, enhancement of democracy, aesthetic/pleasurable, and economic goals of science communication observed by the author can also each be described as constituting different subcultures of science communication. These are just some of the values, norms, beliefs, and goals that permeate the products and practices in science communication, where other mandates such as Mertonian principles (e.g., universalism, disinterestedness), journalistic values (e.g., accuracy, fairness), naturalism, and environmental beliefs (e.g., Hansen, 2016; Medvecky & Leach, 2019; Perrault, 2013; Pigliucci, 2006; Sideris, 2017), infuse at different times and in various ways the social representation that constitute the many subcultures within the mosaic that is the larger culture of science communication. This view of science communication as a multiplicity of subcultures each with interacting, contrasting, and competing cultural mandates, moves away from the simplicity of the three-tier model framework, while recognizing its contribution to describe the various spaces where science is communicated.

I want to quickly mention that throughout this thesis, I will use the term 'culture of science communication' to describe for the most part one particular subcultural space within the larger mosaic that is the actual culture of science communication. Although science communication has existed as long as there has been science, and science has been there "as long as there has been humans" (Alioto, 1993, as cited in Perrault, 2013, p. 37), the specific subculture that I am referring to in this thesis is the communication of Western science in the English-speaking world, with a particular focus on the British/US experience (Atkinson, 1999; Perrault, 2013). Although I am cognizant of the many subcultures of science communication across and within national boundaries and linguistic communities, each of which differs in their historical trajectories and the social meanings that circulate within these (Gascoigne et al., 2020; Trench et al., 2014), I recognise the undue and hegemonic influence that the English-speaking science communication culture has had overall, as a result from many historical contingencies (e.g. the British Empire, US mass culture) that have led to things such as English becoming the lingua franca of scientific research (see Márquez &

Porras, 2020; Tardy, 2004). As such, many of the shared meanings for the global culture of science communication originate from the idiosyncrasies of the aesthetics and discourses in the culture of speakers of the English language in these countries. While this might tempt some to apply any of the results of this thesis beyond the Anglosphere, their generalizability to other cultural and subcultural contexts is a question for future research.

It is also worth noting that the set of social meanings that hold together the culture of science communication are in a constant tug-of-war between stability and instability. Besides the dynamics of interacting, contrasting, and competing subcultural mandates within this space, new meanings are always being created, while old ones change and sometimes fade away (see S. Hall, 2006). Similarly, various cultural processes sustain these social meanings in time (e.g., conventionalisation and standards) (Fiske, 2011). Things such as rituals, customs, routines, mass consumption objects, and many other products and practices that rely on repetition and redundancy give a sense of firmness to the social meanings' sustenance. For example, metaphors of science as a journey, where words and ideas such as "breakthrough, milestone, overcoming hurdles, moving a step closer, breaking new ground, [and] reaching a new frontier" (Hellsten et al., 2008, p. 104), are repeated over and over as conventions in science communication, constituting a core set of social meanings through which people interpret, communicate, and relate to science. While no dictionary definition says that science is a journey, the convention is used and understood by the people within the science communication culture, having various real-world practical and ethical consequences (Hellsten et al., 2008). Attentiveness to the continuous change and contextual nature of the content of the social representations of categories (see Boddice, 2018, 2019) counteracts the slippage into naturalizing meanings that are well understood to be cultural constructions[46].

Finally, I want to highlight how these standards, conventions, and stereotypes (i.e., social representations) work through different aesthetic and discursive formations[47], supporting the redundancies from which people learn social meanings and define science communication's

[46] For a discussion on emotion categories and how these are treated as natural kinds despite being cultural categories see (Barrett, 2017b).
[47] I use Frouws' (1998) definition of discourse as a historically situated "organized set of social representation[s]", "the terms through which people understand, explain and articulate the complex social and physical environment in which they are immersed" (p. 56). There are many definitions of the category 'discourse' along with a contentious debate about which of these is correct (e.g., I. Parker, 1990). The broad definition serves as an analytical tool to describe the repertoires that people use when talking about things and their ability to construct these objects while pointing at their historical and situated nature, without getting too involved in post-structuralist concerns with subjectivity and power debates central to Foucauldian types of analyses (e.g., Hook, 2001).

boundaries with the rest of society. These formations perform boundary work, defining what is and what is not science communication (Broks, 2006), while outlining what is appropriate, relevant, useful, true, and who is allowed to say what, where, when, and how (S. Hall et al., 2013). For example, through how formations distinguish between science and what is non-science or public and expert, boundaries are formed around these categories; performative acts that have a host of sociocultural and political implications[48] (Myers, 2003; Perrault, 2013). Through these aesthetics and discursive formations, objects, events, settings, beliefs, expressions, values, and more importantly for this thesis, emotions, acquire much of their social meanings in the repeated reproduction of particular social representations.

To summarise, and to continue the spatial metaphor, I argue that science communication is a mosaic cultural space that has existed in the interface between science and society. People within this space share a set of social meanings represented in the products and practices of this space. Its main topic is scientific knowledge, though this is not the only set of social representations that circulate in this space. Beliefs, values, stories, identities, ideologies, emotions, and many other forms of representation are also co-constitutive of this space. Although this cultural space's borders are fuzzy and always in flux, some actors are continuously performing boundary work through the use of discursive and aesthetic formations to demarcate and define its borders and the objects within it. At the science communication event, people bring their lifeworld cultures (i.e., experiences) through which they interpret the products and practices in this space, and the distance between their lifeworld culture and the culture of science communication regulates their representation of the social meanings from this space. As people spend more time in this cultural space, they learn the social meanings, slowly becoming more skilled in constituting the preferred and dominant representations, as the distance between their lifeworld culture and the culture of science communication closes. Finally, science communication isn't a static and homogenous culture but rather it is made up of a multiplicity of subcultural spaces, each of which has different, competing, and sometimes contradicting sets of cultural mandates, through which the different discursive and aesthetic formations are mobilised and from which divergent social meanings emerge. All in all, the category of 'the culture of science communication'

[48] For example, many children still portray scientists as old white men with crazy hair and wearing lab coats (e.g., Rawson & McCool, 2014). This representation exists within a particular formation (ways in which we talk and represent scientists), and these ways through which we talk about things, drive children's future career choices, which ends up reproducing and perpetuating the exclusionary (e.g., sexists, racists) content of those formations.

aims to capture the broad and dynamic complex ecosystem of social meanings through which people outside academic spaces make meaning out of scientific knowledge, products, and practices.

3.5. Awe in the culture of science communication

I argue that awe, like all other emotions, is a historically and culturally contingent conceptual category with multiple types that correspond to the particular mandates of the cultures (and subcultures) in which this emotion is represented. People learn awe due to the developmental context in which they are enculturated and the uniqueness of the social interactions and cultural artefacts they encounter throughout their lives. In many situations, awe is mentally represented as a situational integrator, combining internal and external elements of a situation into one coherent script, narrative, schema, action cycle, or some other relational structure that solves a particular goal in a situation and through which a situation is made meaningful in its representation. People's experience of awe is then the result of a situated conceptualization which integrates elements of the situation using the conceptual knowledge that they have acquired throughout a lifetime of interactions with this category to serve a specific function in the situation a person finds themselves in. According to this perspective, then, the stereotypical open-mouth display and "wow" vocal burst, or the feelings of smallness and connectedness that may accompany the exposure to vast and astonishing content, are not innate responses, but rather these are elements of a relatively narrow cultural stereotype through which a person constructs a situation where such responses are warranted. Many other types of awe are out there in the many cultures and subcultures where this emotion is important, assuming a variety of forms (i.e., objects, agents, affect, behaviours, expressions) and functions (i.e., outcomes) in relation to the different mandates in each of these spaces[49].

The category awe, I argue, is valued and has a variety of types in the culture of science communication. Each of these has their distinctive histories and idiosyncrasies responding to the various mandates of the different subcultures (e.g., entertainment, democratic participation, promotion of science) within the larger mosaic of this cultural space. As a result of its value, this emotion is frequently and centrally represented at the science

[49] A version of this paragraph appears in (Silva Luna & Bering, 2020, p. 6)

communication event both as experience (i.e., mental representations) and in its products and practices (i.e., social representations). People learn the various types of awe in their consumption of science communication, over time becoming more skilled in representing these emotion types. More importantly, awe is co-constitutive of many of the objects, agents, beliefs, identities, and other forms of meaning circulated in this space. The various awe types present in science communication both constrain and support the different, contrasting, and sometimes competing cultural mandates.

The *history* and *value* of awe in science communication, the *skill* to conceptualize this emotion displayed by people who participate in this culture, and the *varieties* of its forms and functions, however, have not been investigated. The few studies that have tried to capture the prevalence of this emotion have found, for example, that people in this cultural space can represent this emotion more often (Gottlieb et al., 2018). This kind of study, however, has been done within the classical view of emotions (Keltner & Haidt, 2003).

In the coming chapters, I try to tackle each of the four questions about the *history*, *value*, *skill*, and *varieties* of awe in science communication. Chapter four contextualizes this emotion category by presenting an outline of its history in the English-speaking world and the many varieties it has assumed in science communication through time. Chapter five assesses the value of this emotion by measuring the frequency and centrality of its representation in a cultural product commonly used to enculturate children: picture books. Chapter six evaluates the degree of people's skill with this emotion category in science communication by comparing their representation of awe in a word association task. Finally, chapter seven describes the variety of forms and functions that this emotion takes and the themes unifying its description by science communicators. Throughout these chapters, I follow the situated conceptualization theory, the constructionist view of emotions, and the descriptions of science communication as culture presented in this chapter as the main theoretical and analytical framework, guiding the methods of data collection and analysis, and providing the context through which the results are discussed.

Chapter four - An outline of the history of awe in science communication

History is not merely additive to psychological methods, nor is it merely background. If history's contribution to emotion knowledge means anything then it should mean the disruption of the very starting point of emotion research. It alters the assumptions that researchers take with them to the lab, or to the field, and influences the kinds of questions that can be asked, as well as changing the stakes of the answers to be sought.

– *Rob Boddice*, History looks forward (2020a, p. 132)

4. Introduction

The classical view of emotions argues that whatever representation of awe, there is a stable core to the form and function of this emotion that includes a series of properties (i.e., vastness and need for accommodation), which all descriptions of this emotion must measure against, or they are discarded as not being authentic (Keltner & Haidt, 2003). The term awe, however, tends to be applied to a vast, and elusive, array of experiences, many of which connote very different types of situations (see chapter two). It is used to describe a variety of objects, subjective feelings, phenomenologies, appraisals, behaviours, and other aspects of situations with sometimes very little in common. More importantly, the academic and popular literature invokes awe as a source of humility, surprise, curiosity, transcendence, admiration, connection, or learning among other outcomes - representational varieties of the same category that the classical view doesn't explain (e.g., Keltner & Haidt, 2003; Stellar et al., 2018; Valdesolo et al., 2017). By contrast, the constructionist view of emotions holds that the many meanings that an emotion takes are localized within the cultural context in which they occur (Averill, 1980; Barrett, 2017a; Lutz, 1988; Mesquita et al., 2017). Awe, as I argued in the previous chapter, is rather a culturally constructed emotion category that refers to a variety of situations and outcomes inscribed in sociocultural reality.

Where did the various meanings for awe, in general, and in science communication, in particular, come from? Over the past few decades, historians have observed that emotions have their own histories (Boddice, 2018, 2019). These studies have described the appearance and changes of the social meanings of emotions such as jealousy (Stearns, 1990), empathy (Lanzoni, 2018), and sadness (Sullivan, 2016) over time, demonstrating the situatedness of emotion in time and space. The convergence of these findings with the constructionist views in anthropology, psychology, and neuroscience, means that emotion categories have histories and that to make sense of them in the present and future requires their proper historical contextualization (Boddice, 2018) This aligns with increasing interdisciplinary calls to "always historicize" (D. M. Gross & Preston, 2020, p. 9) the categories of emotion being studied in contemporary research. As the quote opening this chapter suggests, the execution and interpretation of a study on emotions will be significantly improved when the object of study is properly contextualized, meaning, when it is situated in time and space (Boddice, 2020a). Situating the contemporary meanings of awe in historical context puts the studies in the coming chapters in their appropriate sociohistorical context, providing a sense of the spaces where this emotion is represented, the nuances of its multiple usages, and the cultural mandates that imbue them with meanings. More importantly, it might contribute to a deeper understanding of its current uses and functions in the communication of science.

No study, however, has traced the history of the emotion category awe[50]. For the most part, classical view emotion research treats emotion categories as ahistorical (Boddice, 2018), with the research on awe being no exception. Nevertheless, it is possible to trace the outlines of this emotion's history and identify some of its changes in social representation by looking at how it has appeared over time within different aesthetic and discursive formations. It is from the secondary literature of these aesthetic and discursive repertoires how the contemporary varieties of awe can be traced through history.

This chapter maps the history of the category awe with particular attention to science communication. Once I have laid the framework through which I tell this story, I outline this emotion's history from its first appearance in the English language in the Middle Ages to the many themes it displays in the Romantic period. I then describe how this emotion became part of the representational repertoire of science communication from descriptions of wonder in the works of Boyle, Descartes, and Newton, to its contemporary awe-filled practices. Overall, this chapter traces the existence of multiple varieties of awe and their use through time in science communication.

[50] Here I am interested in the history of the category awe rather than the history of the awe experience. The conceptual history of an emotion term is part of that history of experience, yet it doesn't aim to give a complete account of people's felt experience with this emotion in the different historical contexts where it was experienced (see Boddice & M. Smith, 2020)

4.1. A framework to study awe through history

Perhaps the most important representational convention for the human species is language (S. Hall et al., 2013; Lupyan, 2012; Paivio, 1971). People who use the same language share, to an extent, a series of social meanings that makes them members of one of the largest possible group units: the culture of speakers of a language. For example, English speakers use the code of the English language to establish a regularity through symbolic means in the signification of a category by providing placeholders (i.e., English words) (Hoemann et al., 2019; Xu, 2002) for a represented entity. This means that an average literate English speaker will recognize the arbitrary set of three symbols printed on this page, 'a-w-e', organize these into a word, and interpret them using the English language convention (i.e., a social meaning), as standing for an emotional category when it is used as a noun (e.g., she was overwhelmed by awe), an invocation of that state when it is used as a verb in a sentence (e.g., they awed the crowd), or as an adjective related to the state in its compounded forms (e.g., awe-inspiring, awe-filled, awe-commanding) among other things. The conventionalization of this preferred meaning of the word 'awe' in its repeated representation in institutionalized practices and products (e.g., dictionaries, stories, recipes) gives it an ecological regularity in-the-world, from which an average English speaker learns this broad definition in their repeated exposure throughout their lives. The relation of the word 'awe' to its social meaning as an affective experience is somewhat temporarily fixed through those conventions and standards, allowing for its communication among individuals within the same cultural unit (i.e., the Anglosphere). As a result, most English speakers will share, in the broadest strokes, elements of conceptual knowledge about the category 'awe' with all the other average speakers of this language, thus representing this category with a certain degree of similarity.

However, those meanings are only shared among speakers of the English language up to a point. The stereotypical social meanings of any category are always slanting over time, continuously mutating, and being produced and reproduced in different ways, as a result of people's experiences and creativity, regularities in linguistic fluctuation, changes in social structures, political struggles, and technological change, among other factors driving semantic evolution (e.g., Dasher & Traugott, 2002; McConnell-Ginet, 2008). One frequently used example for the change in the social meaning of a categories has precisely to do with awe. The word awful, whose early uses were akin to those of awe-inspiring today, now refers to something categorically bad (Oxford University Press, n.d.-a). Words and categories change meaning, ending up assuming a multiplicity of forms and functions, some of which run out of fashion, or which co-inhabit the cultural space simultaneously. Dictionaries such as the *Oxford English Dictionary* (OED), as repositories of these social conventions, have captured such semantic changes in their job of cataloguing the many usages given to a linguistic representation. This process of cataloguing done by the OED, and other such dictionaries, is one of the many mechanisms of standardizing social meanings within the Anglophone culture and serves as an entry point for investigating their semantic history. In that sense, the OED (Oxford University Press, n.d.-c) identifies the following three stereotypical meanings for the word 'awe' when it is used as a noun:

1) Immediate and active fear; terror, dread.
2) From its use in reference to the divine being this passes gradually into: Dread mingled with veneration, reverential or respectful fear; the attitude of a mind subdued to profound reverence in the presence of supreme authority, moral greatness or sublimity, or mysterious sacredness.
3) The feeling of solemn and reverential wonder, tinged with latent fear, inspired by what is terribly sublime and majestic in nature.

The three senses of awe here described lean towards terror, admiration, and wonder – social meanings that appear today in academic descriptions of this emotion (A. M. Gordon et al., 2017; Keltner & Haidt, 2003; Sundararajan, 2002). These definitions also capture some of the situational elements that appear in contemporary descriptions of this emotion category. Situations such as being in the presence of God or nature, and themes around solemnity, greatness, and mystery are part of these definitions. These limited definitions, however, do not mention the many other forms and functions of awe suggested in the literature review. The lack of reference to encounters with architecture, music, grand theories, animals, works of art, or any of the other situations where this emotion is experienced on the one hand, or to the themes of vastness, need for accommodation, curiosity, humility, beauty, transcendence, smallness, or any of the many other threads used to represent this emotion on the other, indicates the limitations of dictionary definitions in reflecting the complex variations of the social representation of an emotion within a culture as diverse as that made up by all English speakers.

More importantly, while different meanings of awe coexist in this larger culture, there may be more elusive social representations of such category within the many subcultures that make up the broader English-language cultural space. In each of these cultural spaces where 'awe' plays some central role, it will take different normative connotations in response to the mandates of such subcultural spaces (see chapter three). Today, awe has been identified in a variety of subcultures in the English language world including the world of art (e.g., Konečni, 2011), Christian religious communities (e.g., Krause & Hayward, 2015), the tourism industry (e.g., Coghlan et al., 2012), the sports world (e.g., Hodges et al., 2015), the world of magic (e.g., Lamont, 2017), the wellness industry (e.g., F. Williams, 2017), environmentalism (e.g., McShane, 2018), and humanist psychology (e.g., Schneider, 2009), among other spaces. Awe takes a variety of social meanings responding to the mandates of each of these spaces, meanings that freely flow from one subculture to the next in a never-ending exchange within the larger semantic market of the English language culture.

It is worth keeping in mind that the social meaning of a category does not exist in a linguistic vacuum. The ways people use the emotion category 'awe' is always within a particular narrative and rhetorical relation with the many words surrounding it. As discursive psychology reminds us (Edwards, 1999), emotions (and other words) are always described as part of larger patterns of social meanings such as stories, scripts, frames, or themes, that tie different constituent elements of a situation together into an overarching narrative and offer contrast towards potential alternatives of events. These larger patterns of representation that give meaning to 'awe' can be described as the discourses of 'awe'[51] – taken-for-granted repertoires through which people use awe and from which they construct its meaning. The discourses of awe provide the semantic scaffold that ties incongruent elements such as words, phrases, metaphors, common places, ideas, and other forms of linguistic utterances into a coherent network or mapping that people use to make sense of and construct the meanings of this emotion category, delineating how it is represented in situations.[52]

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[51] Lutz and Abu-Lughod's (1990) distinction between discourses on emotion and emotional discourses is helpful to think about these formations Discourses on awe, the way researchers, practitioners, the public, talk about awe are relatively recent and these have been for the most part described in the literature review. Emotional discourses of awe, on the other hand, are not referring to this emotion category but rather are "commentaries on the practices" (Lutz & Abu Lughod, 1990, p. 19) in which awe is part of the situation. This chapter concerns those emotional discourses in which awe participates.

[52] This includes issues about whether it is appropriate or not to experience it, who gets to experience it, where, and when, in relation to what, and the expressions and affordances that correspond to it, among other things.

Besides language, there are many other forms of representations associated with an emotion category. There is an entire semiotic code through which objects, symbols, images, smells, sounds, movements, and other forms of non-linguistic representations function as signifiers to an emotion within a grid of semantic associations in social contexts (e.g., Pernau & Rajamani, 2016). Facial expressions, body movements, places, food, dances, people, events, music, architecture, and many other objects and behaviours signify an emotion category through connotation. For example, in part of the English-speaking culture, there is a code in which expressions such as the open drop-jawed mouth, the tilted head forward, visible inhalations, and the 'wow' vocal burst described in various studies (e.g., Campos et al., 2013; Cordaro et al., 2018; Shiota et al., 2003), stand for 'awe'. The same can be said for images, such as those of panoramic views of waterfalls, oceans, and deserts (e.g., Prade & Saroglou, 2016; Saroglou et al., 2008), giant dinosaurs (e.g., Shiota et al., 2007), or views of Earth from space (e.g., Yaden et al., 2016), which are also part of the shared code of non-linguistic elements through which many English speakers constitute this emotion.

As with discursive repertoires, these non-linguistic (i.e., aesthetic) formations representing awe exist within an extensive semantic network of interlaced linguistic and non-linguistic associations through which people make sense of this emotion (see Pernau & Rajamani, 2016). Together, the discursive and aesthetic formations of awe work in tandem to galvanize the many social representations that this emotion has in the many contexts where it circulates, connecting the various elements that make up its different representations and its many themes to the larger social, political, and cultural world.

The variety of social meanings with which awe is represented today reflects how this concept has been diversely represented over time. No work, however, has examined the evolution of the emotion category 'awe' and its many manifestations over different periods. Having said that, the outlines of this history can be traced in part by reviewing works that have dealt with the discursive and aesthetic repertoires through which people make sense of this emotion: 'the sublime' and 'the wondrous'.[53,54]

[53] I refer to it as a discourse of the wondrous although most of the literature refers to it as a discourse of wonder. I do this to differentiate between the formation and the emotion category 'wonder'.

[54] While awe participates in a variety of other discourses (e.g., religious discourses), I will focus on these two.

There has been considerable academic interest for almost a century in the sublime starting with Samuel Monk's review (Monk, 1960/1935) of its role in the work of various 18th and 19th century English writers. Since then, multiple works have reviewed the sublime from the fields of literary studies (e.g., De Luca, 1991; Nicholson, 1997; Poetzsch, 2006; Weiskel, 1986), philosophy (e.g., Shaw, 2017), or from a historical perspective (e.g., De Bolla, 1989; Nye, 1994). Similarly, the study of the wondrous has caught on over the last few decades after many years of neglect from various disciplines (Vasalou, 2015). The historic inaugural address on wonder by R.W. Hepburn (1980) marks a starting point for various works on wonder appearing in philosophy (e.g., Rubenstein, 2011; Vasalou, 2015), aesthetics (e.g., Fisher, 1998), and history (e.g., Daston & Park, 1998). More recently, ecological and feminist studies have shined a critical light on much of what has been said about these discursive and aesthetic repertoires and their sociocultural roles. This critical attitude to the formations of the sublime and the wondrous can be seen in the works of authors such as William Cronon (1996), Patricia Yaeger (1989), Barbara Claire Freeman (1995), Christopher Hitt (1999), Louise Economides (2016), and Lisa Sideris (2017). Together, this work opens a window for tracing the history of the different meanings underlying awe, a history that informs us about how these conventions are used in science communication today.

However, as lively and intricate as the discussions about the historical trajectories of the sublime and the wondrous are, the many works written on the subject can only explain as much about the history of awe. First, most authors in this area have taken a classical view of emotions. They describe emotion categories such as awe as having a static and universal essence, from which authors in different cultures with different languages and from different periods are allegedly describing the same affective overtones[55]. Only a few authors have taken a constructionist view of emotions[56]. Second, the resources that authors work with, tend

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[55] For example, studies treat Plato's *thaumazein*, Descartes' *etonemment*, and Kant's *Bewunderung*, as the same emotion category as 'wonder' in the English language (e.g., Fisher, 1998; Hepburn, 1980; Rubenstein, 2011; Vasalou, 2015). Constructionist accounts of emotion would have an issue with taking direct translations of emotion words across eras and cultures without explicating the sociocultural practices and representations surrounding these (Boddice, 2019; Boddice & M Smith, 2020). Evidence suggests that words translated as equivalent from one language to another refer to different social and psychological experiences and expressions (e.g., Hurtado de Mendoza et al., 2010; Kayyal & Russell, 2012). This is not to say that the translations circulated in the English language of the works by these authors did not impact how people talked about these emotions in the English-speaking world. It is then important to acknowledge the role that translations of authors such as Plato, Descartes, and Kant have played in inspiring how different writers in the English-speaking world, from Smith to Dawkins, have written about these emotions without taking these to have the same social meaning as the English words. Other forms of semantic borrowing from things like geographic proximity (e.g., multilingualism) result in semantic networks for emotion categories becoming increasingly related (see Jackson et al., 2019). Yet as similar as emotion categories in different languages can be, awe isn't the same as ikei (Japanese), huşu (Turkish), asombro (Spanish), and any other of the countless translated pairings.

[56] This is the case of Lorraine Daston and Katharine Park, who in their work *Wonders and the Order of Nature* (1998) identified the changes in the social meaning of wonder from the High Middle Ages to the Early Enlightenment period. The authors document the changes in the

to bias their accounts around the social meanings of particular artistic and socioeconomic groups. By contrast, the ways by which these emotion words are used by people outside these elite groups are seldom presented.

Furthermore, most studies have a tidy narrative structure within somewhat defined taxonomies to capture the trajectory of the different formations. Some acknowledge the existence of multiple 'micro-narratives' that can give a much more diverse and nuanced sense of the different meanings appearing within these formations, the interaction between these, and their changes through time (e.g., Vasalou, 2015). Every author deals then with an act of balancing the parsimony of clear taxonomies with the messiness of having multiple narratives that do not coalesce into a single unified picture that can be told within a narrative arc. The narrative and taxonomies presented here are a case in point. With various methodological, intellectual, resource, and spatial constraints, the outline presented here is only a broad and modest overview of a history spanning more than five centuries.

Finally, tracing the history of the meanings of a category through its many representations in the historical record is a complicated endeavour because "thought is organic, and every thought in every period is in some way conditioned by other thoughts" (Monk, 1960, p. 2). There are tomes and methods dedicated to elucidating the evolution of a category through time, who try linking different authors, the meanings of what they wrote about, and the social, demographic, technological, economic, and political circumstances through which the studied categories transpired (see Koselleck, 2002). More importantly, scholars argue endlessly about who inspired who, how works should be interpreted, the idiosyncrasies and contexts that could lead to such an interpretation, among many disagreements in literature, philosophy, history, and other disciplines that trace the historical development of a category. For example, there is if little agreement about how the sublime and the wondrous moved through place and time, the taxonomies that should be used to interpret these, and the impact they have had in the past and today[57]. The literature review presented in this chapter is an

objects in the world that "cause" an episode of wonder and the descriptions of its psychological experience, or what the authors call the "objective order […] [and its] subjective sensibilities" (p. 14). They trace these changes by looking at how these emotions' representation stood next to other emotion and non-emotion words. Their description of changes in the representational maps (i.e., discourses) is somewhat similar to some of the changes in the affective tone that Louise Economides (2016) observes in the continuities and changes in the discourses of wonder and the sublime from the 17th-century until today.

[57] See, for example, the arguments of Ashfield and de Bolla (1996) against Monk (1960) in the differences between the English and the German sublime, as well as the rhetorical and the natural sublime.

interpretative attempt at localizing the historical sources of some of the elements of situations and functions that people use today to talk about the category awe, particularly in science communication. I then side with those authors who see the weight of the sublime and the wondrous in the constitutions of people's emotional experiences in the present (e.g., Cronon, 1996; Economides, 2016; Hitt, 1999), rather than with those who see them as somewhat moribund (e.g., Weiskel, 1986). This is my effort at contextualizing the study of the social representation of this emotion today which is presented in the following chapters.

4.2. The history of awe

The next sections look at the historical trajectory of the emotion category 'awe', and the various social meanings it has picked up over the last few centuries. These, I argue, result from socio-political, technological, and cultural changes in the English-speaking world, around which different discursive and aesthetic formations appeared, moved, and changed. The histories of the formations of the sublime and the wondrous regulated much of the production, consumption, and circulation of the representation of awe, all leading to its various social meanings in contemporary science communication. My overview of this complex history focuses on some of the available analytical and critical reviews of the origins and changes in time of the formations of the sublime and the wondrous. This is a literature review where I adapt the linear narrative, and main taxonomies for the evolution of these formations found in the works of authors such as Monk, Shaw, Daston and Park, Nye, Economides, and Vasalou, among others, to the purposes of this work. As a result, the next section begins with the origins of the word awe in religious discourse, to then look at its role in the different iterations of the sublime before the 19th century – rhetorical, natural, and Kantian. Then, the section turns to the origins of the related word 'wonder' within the discourses of the wondrous. Finally, I look at how these two formations met and intermingled with other discourses and aesthetics during the Romantic era, giving rise to many of the social meanings that we associate awe with today. In the subsequent section, I will trace the development and usage of this emotion category in the communication of science through the 19th and 20th centuries.

4.2.1. Origins and religious discourse

The word 'awe' can be traced back to the Proto-Germanic word **agiz-*, from which the Old Norse word '*agi'* (translated often as 'fright') and the Old English '*ege'* ('terror'), derive their meaning (Harper, n.d.-a). By the 14th century, the word was already being used in its current spelling to mean both terror and a form of dreadful admiration in "reference to the divine being" (Oxford University Press, n.d.-c). This can be observed in Psalm 33 of the first complete printed Bible in the English language, the Coverdale Bible of 1535, which includes:

Let all the earth feare the LORDE, and let all them that dwell in the worlde, stode in awe of him (Coverdale, 1975/1535).

Awe as a form of terror towards the godhead is a fundamental emotion in some Christian religious discourses (Fisher, 1998; Otto, 1923; Vasalou, 2015). Otto (1923) describes it as a sense of overpowering, majesty and dread that came in the presence of the divine figure, standing as the cornerstone of much of religious devotion. As in the psalm, Otto refers to the Bible and other religious text's descriptions of awe as a fearful encounter that is made ambiguous by themes of majesty, reverence, and admiration. Overall, these early descriptions of awe are shackled to religious discourses around the encounter with the deity.

The secularization of Europe throughout the Renaissance, however, brought a decline in religious authority and its discourses (Monk, 1960). The word 'awe' would then take new meanings and themes within the many cultural changes Europe experienced, such as the appearance of new humanistic values (see Weiskel, 1986). Nonetheless, the meanings and themes of awe around a religious discourse of the encounter with the deity have been kept alive in the work of thinkers such as Kierkegaard's and his *horror religiosus* (Vasalou, 2015), Otto's encounters with the numinous (Otto, 1923), and Woodruff's most reverent feelings towards something transcendent (Woodruff, 2001; Sundararajan, 2002). This religious discourse of divine encounters was to heavily influence some of the emotional discourses and aesthetics that would become common in Western Europe throughout the 18th and 19th centuries, particularly the discourses of the sublime.

4.2.2. New meanings of 'awe' in the discourse of the sublime

Ideas about the sublime reappeared in Europe around the late 17th century, achieving a critical status throughout the 18th and early 19th centuries in England (Monk, 1960). The secularization and rapid restructuring of social hierarchies, and the twin political and technological revolutions of the era, left thinkers and artists looking for original vocabularies to describe the new forms of social relations appearing in this period (Weiskel, 1986). The work of an anonymous Roman stoic thinker known as pseudo-Longinus and titled *Peri Hypsous* or *On the Sublime* (Longinus, 1996), gave English writers a new conceptual trope that was ripe to describe the anxieties of the time (Weiskel, 1986). After being unearthed in 1674 in a translation by Nicolas Boileau, this book gained enormous popularity throughout the 18th century in England, making the sublime one of the "informing concepts of the age" (De Bolla, 1989, p. 30) and influencing various aspects of the cultural life of the time, ranging from people's aesthetic sensibilities to the role of emergent social institutions.

The idea of the sublime in the scholarship communicates a boundary of reason, whereby words fail to express the encounter with an object or thought, when there is a breakdown of the usual cognitive apparatus through which experience is assessed, and this indeterminacy is evaluated as being part of an order beyond experience (Weiskel, 1986). As a result, the concept of the sublime has been related to the understanding of transcendence, of a vision of what is beyond ordinary experience, or as sensing of what "lies beyond thought and language" (Shaw, 2017, p. 3). This vision of the sublime in relation to a metaphysical order in Western thought was influenced by the religious discourse of the encounter with the deity. This is why some authors characterize sublimity as essentially a secular version of a religious experience under another name (e.g., Cronon, 1996; Fisher, 1998). Other authors, such as Economides (2016) and Hitt (1999), see the emphasis of the sublime in its call for mastery and control, as a formation that defines the limits of what is and what is not reasonable; the sublime allows secular society to define otherness, whether in 'inhuman nature', or in society, against "'irrational' women, non-European peoples, the poor, [and] children" (Economides, 2016, p. 19), confirming "the authority and autonomy of a [reasonable] subject over and against a threatening other" (Hitt, 1999, p. 603). Moreover, these authors describe how the sublime reinforces the "masculinist and humanist agenda critical to the project of modernity" (Economides, 2016, p. 19) through its holding the key to our transcendence from nature. Considering the differences between literary and critical interpretations of the sublime, it is not surprising then that while authors such as Weiskel argue that the concept is today in a moribund state (Weiskel, 1986), others argue that it continues to mediate our relationship to nature (e.g., Cronon, 1996; Economides, 2016; Hitt, 1999), the relations between men and women (e.g., Yaeger, 1989), and people's relationship with science and technology (e.g., Nye, 1994).

Since the appearance of the sublime in Europe, it has merged and fused into many other formations, taking, and giving categories, metaphors, and other forms of representation to and from other discourses and aesthetics. In this giving and taking from various formations, the emotion vocabulary of the sublime which includes emotion words such as ‘astonishment’, ‘elevation’, and ‘admiration’, have come to take new social meanings and themes. ‘Awe’, a word with a religious background, becomes entangled into these semantic networks, associating and interacting with other words in its introduction into the sublime, and acquiring thus a whole new set of ways of being represented. However, this story is not straightforward as the sublime came in different varieties. A broad taxonomy of the sublime can be seen, one showing that the 18th century had at least three varieties according to the themes, objects of focus, and effects. These versions are the *rhetorical*, *natural, and Kantian* sublime[58]. These formations of the sublime came to have different forms and degrees of impact in the many subcultural spaces where these were utilized. However, by the end of the 18th century and early 19th century, during the period identified as the Romanticism, the sublime had infected European culture at large and English culture in particular (Weiskel, 1986).

4.2.2.1. The rhetorical sublime

Longinus’ *Peri Hipsous* can be described as the starting point for the rhetorical sublime (Crane, 1936; Monk, 1960; Shaw, 2017). This book is mostly concerned with the rhetorical styles that cause sublime experiences in an audience (Longinus, 1996). The sublime is both a rhetorical strategy in the vein of the grand style, and a quality of the artist or orator’s mind, which produces an intense emotional reaction on the audience (Monk, 1960). This last quality is beyond the mere oratorical skill, and its sign is on the emotional overtones that can take “violent and even enthusiastic degree(s)” (Longinus, 1996, p. 23) on the audience, giving the “echo of a noble mind” (Shaw, 2017, p. 15). The sublime for Longinus is a source of distinction from which “sensible minds” can recognize the greatness of a person (Crane, 1936, p. 165), legitimizing and assigning power to the figure of the ‘genius’ and their works through which the “quality of their souls shines through” and to which the audience

[58] This is, of course, a simplistic taxonomy of the many ways in which the sublime metamorphosed throughout the 18th century. Scholars such as Shaw (2017) and Ashfield and de Bolla (1996) describe the many authors who used the sublime and adapted it in many different ways to respond to the demands of their context. The categories used here describe the two or three primary variants of such a complex formation.

subordinates itself, as “not to admire [the genius] is to confess oneself lacking in taste and sensitivity” (Crane, 1936, pp. 165–166). The power that the person receives is then manifested in the embodied experience through the emotional reactions of the audience, who is taken as if by a ‘thunderbolt’ into a state of submission and in which “a grand conception may be instilled in the mind without any bothersome appeal to reason or justice” (Shaw, 2017, p. 14). This vision of sheer rhetorical power through which the genius brings the audience to a state of raised emotions, including elevation, ecstasy, admiration, and awe, is the most central theme around the rhetorical sublime (Crane, 1936; Longinus, 1996; Shaw, 2017).

Many 18th-century authors, such as John Dennis and Thomas Stackhouse, continued this tradition of a ‘rhetorical sublime’ whose power lies in language (Ashfield & De Bolla, 1996, p. 28)[59]. Yet a broader version of the sublime, one that went beyond the image of the ‘genius’ and their rhetorical skills, also emerged. Quotes from Longinus’ *Peri Hipsous* were extracted and applied to a context in which the natural world was starting to be seen, not as a strange and hostile place, but one of beauty and adventure[60] (Monk, 1960; Nicholson, 1997; Weiskel, 1986). Authors in this tradition took Longinus’ pagan vocabulary of thunderous ravaging and transport and moulded it to the realities of a Christian worldview increasingly under threat from new perspectives of the individual and the universe (De Bolla, 1989; Monk, 1960). In this moulding and mixing of categories, ideas, and other forms of representation, the concept of ‘awe’ as terror and admiration acquired a new set of social signifiers and associations.

4.2.2.2. The natural sublime

Longinus’ work on the sublime led to interpretations in which the sublime existed in the external world, specifically, as a quality of nature (Monk, 1960; Shaw, 2017). As Monk notes, before the sublime entered Europe, there was “little enthusiasm for natural sublimities” (Monk, 1960, p. 17). Marjorie Hope Nicholson also writes in her work *Mountain Gloom and*

[59] While the distinction of the ‘rhetorical sublime’ and the ‘natural sublime’ that began with R.S. Crane is still used in texts about the sublime (e.g., Shaw, 2017), there has been a long discussion into how true these differences are in the many writers of the XVIII century. For example, Weiskel argues that the rhetorical sublime is “structurally cognate” to the natural sublime (Weiskel, 1986, p. 11) while Ashfield and de Bolla (1996) recognize not only a Longinian tradition but various other forms of interpretations that mix elements of the natural and the rhetorical with many other forms of discourse.

[60] For example, Longinus (1996) writes: “Nature never designed man to be a groveling and ungenerous animal, but brought him into life, and placed him in the world, as in a crowded theatre, not to be an idle spectator, but spurred on by an eager thirst of excelling, ardently to contend in the pursuit of glory. For this purpose, she implanted in his soul an invincible love of grandeur, and a constant emulation of whatever seems to approach nearer to divinity than himself” (p. 28).

Mountain Glory (1997/1963) that before the 18th century, mountains were "warts, blisters, imposthumes, when they were not the rubbish of the earth, swept away by the careful housewife Nature – waste places of the world with little meaning and less charm" (Nicholson, 1997, p. 62). However, the increasing anxieties of modernity creeping from the novel, empirically-driven ways of assessing the world resulted in boredom and disenchantment. In turn, writers began to seek out intense emotional experience in nature as a "homeopathic therapy (…) [and] a cure of uneasiness" (Weiskel, 1986, p. 18) in an effort to guide readers out of the daily and the familiar. The vocabulary of the sublime in Longinus, with its focus on powerful emotions as a result of images of grandeur, was taken by artists and writers of the time and applied to this changing interpretation of the natural world (Monk, 1960). Images of new worlds were opening up the imagination and rupturing the images of order and beauty that dominated previous eras (Economides, 2016; Vasalou, 2015; Weiskel, 1986). Findings in astronomy, geography, and exploration, meant that meanings traditionally assigned to the deity, such as vastness and infinity, were soon slipping to denote qualities of the natural world (Weiskel, 1986). It is in this new semiotic economy where emotional words that would traditionally accompany descriptions of religious encounters with the deity (e.g., awe, fear, love) and the experience of the sublime (e.g., astonishment, elevation, ecstasy) were transposed to encompass natural objects and phenomena, such as the night sky, waterfalls, the ocean, desserts, and mountains, within a secular version of the sublime whereby "a sense of the numinous was diffused through all the grander aspects of nature" (Weiskel, 1986, p. 14). This movement of the powerful themes and emotional vocabulary from the rhetorical sublime to natural objects via religious discourses, is one of the most important characteristics of what is today referred to as the *natural sublime*.

After standing for most of its history as a symbol of fear surrounding encounters with God, the word 'awe' acquired a new set of social meanings within the discourses of the rhetorical and natural sublime. The sublime had created new networks in which the encounter with objects deemed sublime, whether those with extraordinary abilities in the rhetorical sublime or natural objects in the natural sublime, became associated as the 'attention foci' of the various emotion categories that prevailed in this economy. In its relation to religious discourses, the emotion vocabulary of the discourse of the sublime made 'awe' tantamount to the emotions in *Peri Hypsous* of 'admiration', 'elevation', and 'astonishment', words that carry with them social meanings that move it away from the 'fear' and 'terror' of awe's original usage. The social meaning of ‘awe’ began then to slip through the discourse of the sublime into a more positive connotation, in relation to the semiotic networks that came to dominate the forms of representation in the second half of the 18^{th} century and the early 19^{th} century.

As an example of this shift, consider *On the Sublime and the Beautiful* by the Irish politician, philosopher, and essayist Edmund Burke (1990/1757). In this work, the formation of these networks of signification can be observed, as the meaning of ‘awe’ slants into new domains through the discourse of the sublime, in its contiguity to other emotion and non-emotion words, which correspond to the aesthetic sensibilities and social necessities of the time.

For Burke, the original meaning of the word ‘awe’ describes an overwhelming terror that “accompanies the idea of power” (Burke, 1990, p. 77). The ultimate source of this awe-inducing power is seen as derived from God:

In the Scripture, wherever God is represented as appearing or speaking, everything terrible in nature is called up to heighten the awe and solemnity of the Divine presence. (...) The earth shook, (says the Psalmist,) the heavens also dropped at the presence of the Lord (p. 79).

The religious association to the emotion concept sustains the original social meaning of the emotion word, which is preserved in the religious discourse of the encounter with the deity. However, the meaning of awe as terror begins to slant in the association that ‘awe’ acquires with other words in its emotional neighbourhood. This can be seen in the following passage:

In all these cases, if the pain and terror are so modified as not to be actually noxious; if the pain is not carried to violence, and the terror is not conversant about the present destruction of the person, as these emotions clear the parts, whether fine or gross, of a dangerous and troublesome incumbrance, they are capable of producing delight; not pleasure, but a sort of delightful horror, a sort of tranquillity tinged with terror; which, as it belongs to self-preservation, is one of the strongest of all the passions. Its object is the sublime. Its highest degree I call astonishment; the subordinate degrees are awe, reverence, and respect, which, by the very etymology of *the words, show from what source they are derived, and how they stand distinguished from positive pleasure* (Burke, 1990, p. 123).

Here, there is a move from an exclusively negatively valenced emotion, towards a more ambiguous experience of 'delightful horror' or 'negative pleasure' through the sublime. It is in moments like this where 'awe' acquires a new social meaning away from the traditional association with terror and into a new semiotic economy in its relationship with astonishment, reverence, and respect, taking, perhaps, a neutral or perhaps positive sense of esteem and worship towards that which the 'awe-inspiring' signifies. Within these new networks of associations, the emotion concepts used by Burke are exchanging meanings; reverence, respect, and astonishment come to be associated with the terror in 'awe', and 'awe' takes from these the aesthetic, behavioural, and phenomenological elements carried by these other emotion words.

More importantly, Burke lists the themes that are to be associated with the sublime and catalogues the objects which possess these qualities. Qualities traditionally associated with God, such as powerfulness, magnificence, obscurity, silence, and infinity are all now qualities that cause emotional reaction that can be thought of as sublime. One of these Burkean themes, vastness, was to become central to the contemporary conceptualization of this emotion (Keltner & Haidt, 2003). Likewise, objects such as "a tower a hundred yards high, or a rock or mountain of that altitude", "the cloudy sky (…) and night", "the ocean" and many such natural objects that possess these qualities are considered sublime and can cause people to experience awe (Burke, 1990). These lists of objects and their attributes calling the sublime were reasonably common throughout the 18th century, found in the works of Dennis, Addison, Akenside, Baille, and many other writers who wrote essays on the topic (Ashfield & de Bolla, 1997; Shaw, 2017). However, Burke's book was to be the most influential work on the subject, going through multiple re-prints both in the United Kingdom and the United States after its original publishing in 1756 (Nye, 1994). The popularization of this specific set of social meanings and themes around admiration and vast natural landscapes that the natural sublime promotes might explain the many usages and associations of the word awe that contemporary English speakers have inherited[61].

There is still in Burke's work, however, an ambivalence about what the source of the sublime is, as he recognizes that God is the ultimate source of the sublime (Burke, 1990; Shaw, 2017). It was German philosopher Immanuel Kant who managed to synthesize a century of literature on the sublime within his philosophical system, which favours the subjective, rather than the religious, point of view. Kant's writing in this area was widely read in his time and, along with Burke's oeuvre, continues to have a significant hold on the subject's discussions to this day.

4.2.2.3. The Kantian sublime

For Kant, the sublime resided in a process whereby reason becomes aware of itself and then conquers its own limits. The German philosopher spent a large section of the third book in his critique series, the *Critique of Judgement* (Kant, 2000/1790), dedicated to defining the characteristics of this process. This new formation displaces attention away from the objects towards an understanding of the mental steps that make up the sublime moment.

Kant's sublime considers its three narrative stages (Hitt, 1999; Weiskel, 1986). The first stage is that of calm or stasis before the encounter. The mind is at ease going about its everyday life. Then it gets overwhelmed with feelings of incomprehension at the presence of an idea or object that cannot be represented as a result of its boundlessness and formlessness that calls into question the person's judgement (Shaw, 2017). This incomprehension can result from an encounter with spatial or temporal magnitude, which the philosopher labels the *mathematical sublime*, or from a sense of overbearing power, the *dynamic sublime* (Kant, 2000/1790). Examples of the mathematical sublime can be sequential objects that lead to the idea of infinity or omnipresence, while objects that bring in the dynamic sublime are usually in nature such as the ocean, mountains, and storms. This second moment of encounter is marked through emotion categories such as astonishment, awe, and admiration. However, the mind can return from this imbalance as reason triumphs over the object. In this final stage, the

[61] Consider how the literature about 'awe' in psychology continues citing Burke's work (e.g., A. M. Gordon et al., 2017; Keltner & Haidt, 2003; Piff et al., 2015) and how grand natural vistas are the paradigm method to elicit 'awe' in lab experiments (e.g., A. M. Gordon et al., 2017; Valdesolo & Graham, 2014).

mind conceives its incapacity to stand against the object's magnitude yet becomes aware of its capacity to represent it (Shaw, 2017). For example, while the concept of infinity is inconceivable, reason can hold the concept of infinity together. The Himalayas also look vast and insurmountable, but people have ascended its highest peaks through ingenuity. Being able to hold infinity conceptually or overcoming our smallness as creatures through reason's powers is a transcendental moment in which it is possible to get in touch with the *a priori* principles that, according to Kant, hold together all experiences (Shaw, 2017). This ability to transcend objects that are beyond comprehension frees reason from the bounds of nature and the imagination (Kant, 2000; Nye, 1994; Shaw, 2017). In this triumph of the human mind over nature, the sublime becomes a discourse of understanding and transcendence from human limitations, where reason, rather than God, is the ultimate source of the sublime. The products of reason such as mathematical formulas, philosophical ideas, and complex concepts enter the semantic network of objects that connote powerful awe-like reactions. Similarly, its process is akin to the theme of accommodation; the theme at the centre of current scientific definitions of awe (e.g., Keltner & Haidt, 2003).

As translations of Kant's works appeared in English, writers such as Blake (De Luca, 1991), Coleridge, and Wordsworth (Shaw, 2017) took the language and narrative structure of the discourse of the sublime and appropriated many of its tropes and rhetorical devices. These authors did not just borrow from Kant's sublime, but also many of the general implications of his philosophical ideas, for example, his move towards subjectivism, the affirmation of the individual, the primacy of the imagination, and the possibilities of art to transcend experience (Monk, 1960; Shaw, 2017; Weiskel, 1986). These ideas proved central to much of a new artistic movement that emerged through the late 18th and early 19th century; a collection of artists and thinkers that today are referred to as the Romantics.

Multiple works about the role of the sublime in Romantic literature and its influence today have emerged over the past century (e.g., Monk, 1960). Many of these analyses have looked at the sublime's focus on the grandest of nature as an object of inspiration and the glorification of the subject, in what Poetzsch (2006) calls the "mountaintop paradigm of the sublime". For example, works such as the *Romantic Sublime* (Weiskel, 1986) have focused their attention on the "big six" of Romantic literature (i.e., Wordsworth, Blake, Coleridge, Byron, Shelley, and Keats) and these writers' descriptions of transformative sublime encounters with expanding vistas, in solitude, and foreign lands. This work created the stereotype of the "lone wanderer, usually male, who, exhausted by the grind of the diurnal round, seeks solace, refreshment or inspiration in the primeval purity of nature, and there discovers some trace of transcendent otherness" (Poetzsch, 2006, p. 9). The idea of vast natural objects eliciting intense emotion reactions in the natural sublime, and the way these lead to changes in perspective in the Kantian sublime, have been since this period staples of the discursive and aesthetic traditions of the English language. Today, the mountaintop version of the sublime can be encountered as one of the main stereotypical representations of awe; it is even used in psychology experiments to elicit awe under controlled laboratory conditions (e.g., Bai et al., 2017; Shiota et al., 2011).

More recently, some scholars have identified a series of other discursive and aesthetic formations running parallel to the sublime in the work of Romantic authors. These scholars have constructed a much more complex view of the many artists in this movement, their varied aesthetic sensibilities, the multiplicity of sources from which they took inspiration, and the many representational repertoires leading to new networks of association. Critics have unearthed many of the themes that the Romantics mixed with the sublime, such as those around the beautiful and the quotidian that contest the traditional narratives of a monolithic conception of the sublime in Romantic literature and its influence today (e.g., Economides, 2016; Poetzsch, 2006). Such images of the pastoral, the beautiful, the quotidian, and most importantly, ideas about the wondrous, converged with the sublime throughout this period, resulting in new forms of representation and signification for many categories, including the emotion 'awe'.

4.2.3. The discourses on the wondrous

The emotion word 'wonder' has obscure origins. Derived from an unknown Proto-Germanic word, the term was already used in the Old English as the noun '*wundor*' in works such as Beowulf to describe a marvellous object, and as an intransitive verb '*wundrian*' as in, to be struck with astonishment or a feeling of surprise (Harper, n.d.-b). By the High Middle Ages, the word was already used in its current spelling to describe an emotional state (Oxford University Press, n.d.-e)[62]. Using a constructionist account, Daston and Park (1998) note the

[62] Arguing from a classical emotions view, various authors trace the social meaning of wonder to Plato and Aristotle's works, whereby, allegedly, philosophy began with this emotion (e.g., Fisher, 1998; Rubenstein, 2011; Vasalou, 2015). These works take an essentialist view

various changes in the social meaning and themes around wonder, through the Middle Ages and to the early Enlightenment period. These authors described multiple formations of the wondrous appearing over the course of centuries, including its religious, lay, and scientific versions.

The authors trace the origins of the religious discourse of the wondrous to European readings of Augustine of Hippo, who argued that there was no distinction between the objects described as wondrous and everyday things. As God had created everything, all was a reflection of the divine will and power, and hence a potential object of wonder (Daston & Park, 1998). This motif about the potentiality of anything to be wonderful was to inspire many writers and thinkers throughout the ages (Daston & Park, 1998; Vasalou, 2015). In this religious formation of the wondrous, the social meaning of the emotion word 'wonder' was accompanied by themes around appreciation, humility, and gratitude that stood in relation to that wholeness of existence.

The second of these discourses of wonder was more lay in tone and would be related to "both sacred and secular marvellous objects that defined the limits of people's knowledge and understanding" (Daston & Park, 1998, p. 16). Through the Medieval period and into the Renaissance, collections of marvels[63] sprang up through Europe, becoming symbols of prestige and reputation for elites who became obsessed with collecting rare specimens and artefacts in their *Wunderkammers*. The emotion of wonder acted as a technology through which the practices that signified the power of the elite were embodied in the emotional reactions to these rarities (Daston & Park, 1998). Wonder took social meanings and themes around the marvel and surprise provoked by the novel and rare object.

However, new forms continued to emerge as a function of Europe's many cultural shifts through the late Renaissance and into the 17th century. 'Curiosity', a word that from antiquity had had negative connotations as the vice of wanting to know "that which did not concern

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of this emotion. For example, the '*thaumezein'* of the ancient Greeks is taken to mean the same as the current emotion word 'wonder' and is described as an innate human capacity (e.g., Fisher, 1998; Vasalou, 2015). While elements of the situation in which *thaumezein* occurred might resemble those of current descriptions of wonder, and the writings of these two authors enormously influenced Western thought, it is very hard to make a one-to-one correspondence between these two emotion categories from a constructionist framework.

[63] The objects of wonder changed through the ages. So, while "the African pygmies, the mysterious lodestone [and] the glowing carbuncle" were all considered objects of wonder, for a relatively long time, other objects, such as the basilisk, comets, and unicorn horns, lost their appeal as they were debunked or demystified (Daston & Park, 1998, p. 17).

one" (Daston & Park, 1998, p. 305), and which had no relation to wonder, became, in the works of early European scientific thinkers such as Hobbes and Descartes, a positive virtue and an ally to wonder. This new scientific wonder, surrounded by themes of curiosity and learning, was central to much of the early scientific endeavour and, as I argue in a later section, to the practices involved in the constitution of early contemporary science communication.

Around the 18th century, however, wonders, which had been a sign of distinction for the European elite for centuries, became "vulgar" to their eyes, with people from all walks of life claiming to possess objects of a similar fashion, and shows travelling around the continent displaying curiosities for popular entertainment (Daston & Park, 1998). Moreover, scientific wonder lost some of its appeal throughout the 18th century. The objective detachment beginning to be expected of natural scientists as a function of their scientific labour, relegated descriptions of wonder (which were rife in the work of 16th and 17th century naturalists) to autobiographies or introspective commentary about their own research (Daston & Park, 1998). This coincided with the rising to prominence of the sublime during the Romantic period, which would turn wonder into something "almost beyond recognition" subsuming much of it into its "natural and moral order" of things (Daston & Park, 1998, p. 362). It is during this critical junction that many of the varieties of awe being used today in science communication were first established.

4.2.4. Awe in the Romantic period

During Europe's Romantic period (which lasted from the late 18th to the early-middle 19th centuries) the semantic networks of powerful emotional experiences of the sublime and the formations around the wondrous came together (Dalston and Park, 1998). Within this blending, the emotion categories awe and wonder became closely associated, being paired up in descriptions of sublime and wondrous situations, to the point of becoming almost interchangeable terms. It is here, I argue, that the emotion word 'awe' acquired a new set of social meanings and themes related to wonder, such as the marvellous, the rare, humility, appreciation, and curiosity, far removed from the themes of the terrible and dreadful reverence on the one hand, and astonished transcendence on the other, related to the sublime. More importantly, while the formation of the sublime was at the core of the discourses and aesthetics of the English Romantic movement (Monk, 1960), the explosion of ideas that came with the Enlightenment allowed many other formations, such as those around beauty or the quotidian, to become entangled in this semiotic economy, thus providing a large variety of novel themes to the categories of awe and wonder. All these developments were to permeate the work of early contemporary science communicators.

At the centre of the transformation of meanings of awe, was the newfound close association between the sublime and the wondrous. To illustrate this pairing, consider the passage below from Blake's poem *Milton*, published in 1810 (cited in Economides, 2016, p. 8). While still circumscribed within the ideas of the sublime, it guides the audience towards new meanings and themes for the word 'awe':

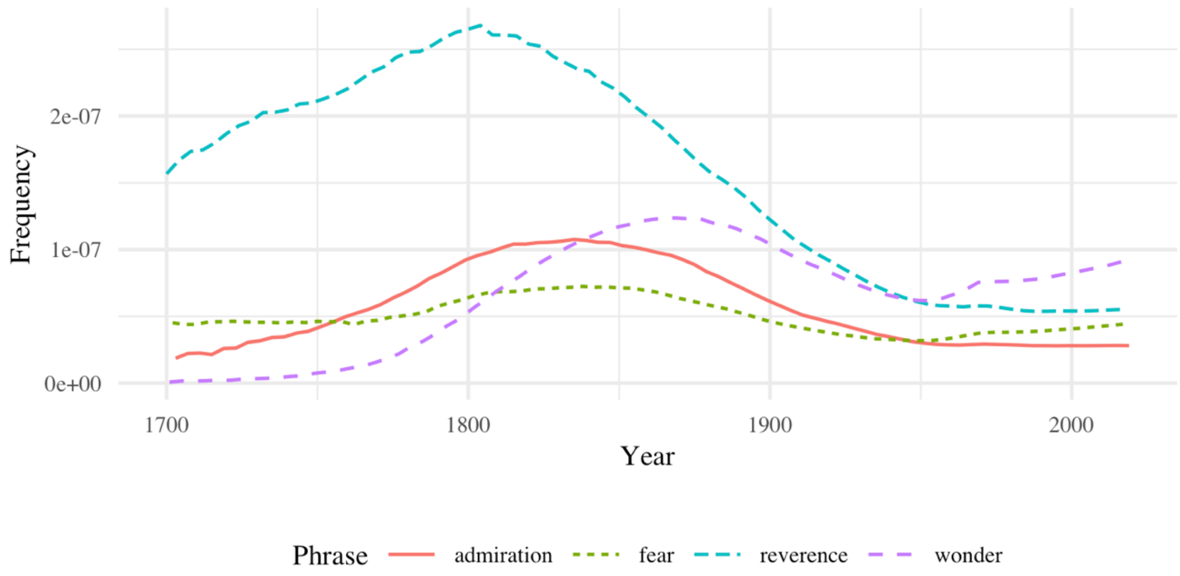
The Lark sitting upon his earthly bed: just as the morn
Appears; listens silent; then springing from the waving Corn-field! loud
He leads the Choir of Day! trill, trill, trill, trill,
Mounting upon the wings of light into the Great Expanse:
Reechoing against the lovely blue & shining heavenly Shell:
His little throat labours with inspiration: every feather
On throat & breast & wings vibrates with effluence Divine
All Nature listens silent to him & the awful Sun
Stands still upon the Mountain looking on this little Bird
With eyes of soft humility, & wonder love & awe. (Part II: Plate 31: 28–38) (Blake, 2002, p. 213)

In this part of the poem, Blake describes the image of a delicate lark singing at dusk, where the vastness and command of the great expanse and heavenly shell (i.e., the natural sublime), is juxtaposed to the smallness, love, and humility characteristic of religious versions of the wondrous and other discourses around the beautiful. The images of chirping, wings, and feathers, stand in sharp contrast with the 'awful Sun' and the 'Mountain', highlighting the difference between the two formations and affording "new perspectives on natural phenomena which might otherwise be perceived as 'mundane'" (Economides, 2016, p. 11).

More importantly, wonder, a word not found in Burke's book to describe the sublime, half a century later sat comfortably next to awe, a pairing that is still widely used today. Following the adage of distributional semantics models (Andrews et al., 2009; Vigliocco et al., 2009) "You shall know a word by the company it keeps" (Firth, 1957, p.11), a quick search in Google Books' n-gram function (figure 4.1) clearly shows the semantic shifts for the word awe in the increasing use of the phrases 'awe and wonder' and 'wonder and awe' in the English language between the publishing of Burke's landmark *A Philosophical Enquiry into the Origin of Our Ideas of the Sublime and Beautiful* in 1757, and Blake's writing of *Milton* between 1804 and 1810. As this figure illustrates, the pairing of these two words increasingly found a place throughout the second half of the 18th century. However, as the Romantic period came into full swing, the paired usage of the two words accelerated, reaching its zenith around the time Darwin published his treatise on natural selection, *On the Origin of Species*, in 1859.[64]

Figure 4.1

Google Books' N-Gram Results for ' and awe' and 'awe and *'*



In this linking between the sublime and the wondrous, awe took on a host of new themes. In the same way that an image of the commonplace, as in Blake's lark in *Milton*, is depicted as sublime, an extract from a 1797 poem by Anna Laetitia Barbauld, titled *Washing Day* (cited

[64] It is worth highlighting that the pairing declined for almost a century until today, where it has reached a similar popularity level as it had during the Romantic period.

in Poetzsch, 2006, p. 116) shows some of these new social meanings that awe takes from more typical 'wondrous' formations:

(…)*well remember, when a child, the awe*
This day struck into me; for then the maids,
I scarce knew why, looked cross, and drove me from them: Nor soft caress could I obtain, nor hope
Usual indulgencies; jelly or creams,
Relic of costly suppers, and set by
For me their petted one; or buttered toast,
When butter was forbid; or thrilling tale
Of ghost or witch, or murder-so I went
*And sheltered me beside the parlour fire(...)(*58-67) (Barbauld, 1874, p. 94)

The author associates awe with the child-like sense of wonder in its descriptions of a washing day; a situation that has nothing to do with the vast natural landscapes or rhetorical prowess of a genius that are characteristic of the sublime. More importantly, in the inclusion of emotion categories reserved for powerful encounters with nature within discourses around the quotidian, both awe and the familiar domicile space acquire new social meanings, essentially grounding the former and elevating the latter (see Poetzsch, 2006).

Coleridge (cited in Economides, 2016, p. 37) also bridges the sublime and the child-like sense of wonder in his description of a genius as someone who can:

…carry on the feelings of childhood into the powers of manhood; to combine the child's sense of wonder and novelty with the appearances which every day for perhaps forty years had rendered familiar: (…) this is the character and privilege of genius, and one of the marks which distinguish genius from talents (Coleridge, 1969, p. 73).

Here, Coleridge merges the wondrous in the image of the child's 'sense of wonder' and the themes around novelty, with the figure of the genius from the rhetorical sublime (Economides, 2016). Wonder and awe are conceptualized as emotions that can bring about a change in perspective, a new set of schemas through which old knowledge is brought from indifference towards the foreground of our cognition, a theme known in art and philosophy as defamiliarization (Economides, 2016; Vasalou, 2015). Importantly, defamiliarization secularizes the ability in the religious discourse of the wondrous through which a change of perspective can make any object wonder-filled through the touch of the divine (see Daston & Park 1998). Defining the genius as the type of individual who can carry the "child's sense of wonder" into adulthood – a defamiliarization ability through which they can turn anything into something novel and awesome – is yet another instance of the interaction between the formations sublime and the wondrous to create new meanings that strongly reverberate into today's discussions (see Sideris, 2017; Vasalou, 2015).

Economides (2016) finds similar amalgamations of the sublime and the wondrous with other formations around themes of the beautiful and the pastoral in the work of the Romantic poets. Both Burke and Kant describe the beautiful as an aesthetics that is the direct opposite to the sublime. While, on the one hand, the sublime is defined in terms of 'manly' "fortitude, justice, and wisdom" (Burke, 1990, p. 100), beauty is treated as a "quality, where it is highest, in the female sex, [and that] almost always carries with it an idea of weakness and imperfection" (Burke, 1990, p. 100). Besides the problematic gender dynamics involved in their definition of these aesthetics (see Freeman, 1995; Yaeger, 1989), the beautiful was then seen as the anti-sublime (Economides, 2016, p. 55). Similarly, the pastoral aesthetic stood in contrast to the sublime (e.g., Dekker, 2014; Economides, 2016). The pastoral's emphasis on harmony, greenery, and locality contrasts to the sublime's value of tension, darkness, and remoteness, which Burke explains, "an immense mountain covered with a shining green turf, is nothing, in this respect, to one dark and gloomy" (Burke, 1990, p. 75). Some Romantics, however, had no difficulty in taking elements of the beautiful, and the pastoral into their network of signifiers and signifieds of the sublime and the wondrous. For example, Coleridge describes wonder and curiosity towards visions of the beautiful and pastoral in his celebrations of nature (Economides, 2016, p. 56). The poet displays in many of his works a sense of tranquillity, harmony, and radical openness to the environment characteristic of pastoral, beautiful, and wonder-filled aesthetics (Economides, 2016, p. 28). Economides (2016) also observes how some of the poetry of authors such as Wordsworth or John Clare, through which 'awe', 'wonder', and other similar emotions, could now be ascribed not just to powerful encounters with the sublime but also to the small, the lovely, the harmonic, the domestic, and the mundane.

These are only a few examples of the many ways in which the Romantic period served as a melting pot for the combination of many discourses and aesthetic formations through which the category 'awe' acquired many of the social meanings and themes that we use to talk about it today. From the sublime, it would take meanings related to terror, elevation, and admiration, and themes of vastness and accommodation. From the wondrous, it would relate to categories such as marvel, astonishment, and wonder, as well as take ideas about defamiliarization, humility, and curiosity. Similarly, it was also to acquire from other formations many other meanings and themes such as modesty, beauty, ordinariness, and gratitude, which are present in today's descriptions of this emotion category (see chapters two and seven). Finally, the sublime and the wondrous have contributed to the stereotypical representation of the situational menagerie ascribed to awe. Whether encounters with outstanding people, natural objects, or the products of reason (e.g., mathematical formulas) through the sublime, or rendezvous with marvels and eccentricities from the wondrous, these discursive and aesthetic formations demarcated and constituted the situations where awe was experienced and expressed. This set of social representations forms the basis of many of the varieties of awe that we currently see represented in the English-speaking world.

Throughout its history, however, different subcultural groups of English speakers have taken and used these various social meanings in different ways, incorporating them into their products and practices in relation to their idiosyncrasies. In fact, some groups give a central place to certain versions of this emotion, adapting its meanings to their particular cultural mandates; processes of appropriation, circulation, and representation with their own social and historical trajectories. For example, whereas specific religious cultural spaces have used social meanings for awe and wonder, with a continued emphasis on terror and admiration and themes of transcendence, elevation, and humility (e.g., Otto, 1923; Sundararajan, 2002), popular practices in the entertainment industry, such as tabloids or the pages of the Guinness World Book of Records, still contain versions of the awe as marvel over rarities and oddities, reminiscent of the *Wunderkammer* (Daston & Park, 1998). The many varieties of awe within the different subcultures, which have given it a place in their representational repertoire, have had their own unique histories. However, they feed one another in the larger and shared cultural spaces in which English language speakers participate, while at the same time changing through time in response to the many social, technological, political, economic, and other challenges that come with every epoch. This is also the case for the varieties of awe in the contemporary culture of science communication, a culture whose original practices and products were heavily influenced by the Romantic movement, and which from its inception positioned awe in a central role in its representational repertoire.

4.3. Awe in the culture of science communication

Varieties of awe, with their many social meanings and themes, have been in use throughout the history of contemporary science communication. However, there is no history of this emotion category and the different senses it took through time in this cultural space. The following sections are my attempt to outline such history. I rely heavily on authors such as Daston and Park (1998) and Nye (1994) to trace the outlines of this history, following the appearance and usage of this emotion category as part of the formations of the sublime and the wondrous; formations which have been central to the ways science is talked about with non-expert audiences.

I begin this section by going back to the genesis of Western science and describe how wonder, in particular, was part of its vocabulary from its conception. Then I describe the appearance of English science communication practices at the beginning of the 19th century and how the Romantics heavily influenced early practitioners in their treatment of awe and wonder. Next, I describe how novel formations of the sublime and the wondrous, such as the technological sublime, the nuclear sublime, and the environmental sense of wonder have become part of how science has been communicated over the past two centuries, adding new representational repertoires to descriptions of this emotion in this space.

4.3.1. The wondrous and the sublime in Western science before the 19th century

Discourses of the wondrous have been closely entwined with Western science products and practices[65] in general, and its English-speaking community in particular, from its early days in the 17th century (Daston & Park, 1998). As described earlier, these formations had been inherited from the many cultural practices of wonder during the Renaissance, such as the *Wunderkammer.* The curiosities and miscellanea found in these *cabinets of*

[65] I acknowledge the very problematic nature of the construct of Western science as it imposes a narrative that, for example, ignores the influences of previous eras and other cultures (see Daston, 2017). Here I use it to refer to the particular knowledge production practices that began to form in Western Europe and particularly in England and France around the 16th and 17th centuries (e.g., the Royal Society, the scientific journal).

curiosities were so much part of the zeitgeist of the late 16th and early 17th centuries that authors such as Francis Bacon included their cultural bearing into their program of methods and epistemologies for the new natural philosophy. Works such as the *Novum Organum* and the *New Atlantis* would have a later influence on the constitution and ethos of the Royal Society through their impact on scientific luminaries such as Boyle, Hook, Huygens, and Newton (Daston & Park, 1998).

Although the history of the Wunderkammer can be traced back to the relic collections of medieval times and through the *Schatz*- repositories of the Renaissance, the 17th century saw an explosion in the popularization of such cabinets (Daston & Park, 1998). Not only royalty and the wealthy collected such marvels, but educated elites such as scholars, lawyers, physicians, merchants, and institutions (including medical schools, universities, and eventually academies), were now bringing together works of craftmanship, exotic objects from far-flung places, natural rarities, and classical antiquities to showcase curiosities in carefully curated spaces. The function of many of these collections was to display the power and wealth of rulers and individuals who used their resources to set up impressive displays that would leave admirers ‘dumbstruck’ with marvel (Daston & Park, 1998). People would travel across Europe to see the marvels in these collections and experience the emotional menagerie these would elicit. A lay discourse of wonder focused on marvellous objects, and the intense emotions these collections brought, was at the time very much part of European culture.

In this cultural milieu of the 17th century, curiosity and wonder were bound together as a “sensibility of inquiry” towards understanding the extraordinary (Daston & Park, 1998, p. 301). Bacon and others drew inspiration from the practices of the *Wunderkammer* in their conceptualization of the practices of natural philosophy (Daston & Park, 1998).
The *Wunderkammer’s* objects demanded a motivational commitment to keep up the sustained level of attention that their study demanded. Authors such as Bacon and Hobbes then reconceptualized curiosity as a restless desire to understand these objects (Daston & Park, 1998, p. 307); a motivation that resulted from the wonder and marvel they generated. It was in this new association between curiosity and wonder, where wonder acts as an engine of encouragement which dissipates once investigation begins, that a new sensibility of enquiry, and a new emotional discourse of the wondrous, would form at the centre of the scientific

pursuit. The wonders of the *Wunderkammer* and the new "sensibility of inquiry" in authors such as Bacon, had an immense influence on the scientific empiricism that the Royal Society promoted in its early decades. The instrumental view of wonder as leading to curiosity drove the research ethos of the time, becoming commonplace in the writings of natural philosophers such as Hooke and Newton throughout the 17th century.

Other themes around wonder, however, began to percolate into the writings of scientists. Authors such as Hooke, for example, described how the act of intense observation, could turn the common and domestic into the rare and the marvellous (Hooke, 1969, as cited in Daston & Park, 1998). This idea that everything is potentially wonderful, present in religious discourses of the wondrous and pursued later by Romantic poets and other artists (i.e., through 'defamiliarization'), characterized wonder as an emotion that dwells on the object; a dwelling parallel to the theme of a 'sense of wonder' at everything in the world. Wonder and curiosity could potentially be sustained, working not as a means to an end, but as an end in itself (Vasalou, 2015). These two conceptualizations of the wondrous (instrumental and the sense of wonder) were to become competing formations in the communication of science (Sideris, 2017).

However, the formations around wonder in science would decline throughout the 17th and early 18th centuries. Even though Bacon had made wonder an important part of the scientific ethos, he also had cautioned against the dangers of too much wonder, arguing that its excesses lead to "broken knowledge" that resembled "vain admiration" (Bacon, 1872, as cited in Daston & Park, 1998, p. 317). Similar admonishments appeared in the work of Boyle, Descartes, and others, who feared that wonder could lead to a paralyzed stupefaction that could freeze rather than encourage enquiry, amongst other issues that could result from its excesses. Furthermore, after the disastrous wars of the 16th and 17th centuries, where religion had played an essential role in their motivation and sustenance, the intellectual elites of Europe in urban centres such as London and Paris, began to view wonder and its role in rousing enthusiasm and superstition, as politically dangerous (Daston & Park, 1998). A mixture of fear, novelty, and admiration for prodigies, miracles, and marvels, had served as the powder keg for revolutionary fervour and pathological fanatism. For the educated elites, the wondrous became associated with chaos and social disorder. Marvels and miracles were reclassified as vulgar objects that aroused vulgar passions, including wonder. Such emotions were seen as leading to superstition, enthusiasm, and a general ignorance that could only be tamed by reason and the methods provided by objective, 'emotionally neutral' science. In short, wonder had lost its appeal as a motivator of inquiry and was downgraded to "the level of gawk" (Daston & Park, 1998, p. 326).

More importantly, the traditional descriptions of the wondrous were replaced by the up-and-coming new aesthetic, moral, and metaphysical sensibility of the European elites: the sublime (Daston & Park, 1998). A. G. Gross (2018) traces the appearance of the sublime in science to the work of Adam Smith, who in his *History of Astronomy* associates powerful natural events of interest to scientists, such as a solar eclipse, to a sense of uncertainty that leads to awe-like emotional reactions. Similarly, Smith saw the higher abstractions of mathematics and other sciences, in their superior exertion of reason's power over matter, as sublime. Vast natural objects studied by science and the powers of the scientific mind and knowledge entered the semiotic economy of the sublime. Authors such as Burke and Kant already recognized these objects' presence in their natural and mathematical descriptions of the sublime. However, it was the work of Smith (A. G. Gross, 2018), Davey (Holmes, 2008), and others who constituted the *scientific sublime*, explicitly using the themes of the natural and Kantian sublime around vastness, transcendence, and the elevation of reason, in their references of the scientific pursuit.

The foregoing works, however, were the last embers of the use of affective language in the culture of science. Throughout the 16th, 17th, and 18th centuries the communication of science was for the most part concerned with reaching all the educated elites of Europe, which is the reason why scientific texts were written in personalized and accessible prose (Perrault, 2013). The cultural boundaries between science and the rest of society were tepid at best, as science was not clearly demarcated from philosophy, theology, ethics, or other knowledge pursuits (Perrault, 2013). The profound societal transformations accelerating in the late 18th century, with trends such as the increasing specialization of the sciences and its professionalization in the universities, academies, and journals, created a growing estrangement between science and society (Atkinson, 2004; Bensaude-Vincent, 2001; Hanauska, 2019; Perrault, 2013)[66]. As

[66] It is most important to note that this is a crude oversimplification of the non-trivial process through which western science and contemporary science communication became their own separate spaces. As Hanauska notes referring to the period before 19th century "it would be a naïve and non-historical view to distinguish between scientific communities and their traditions of communication and non-scientific communities

a result, the language of scientific discussion, such as in journals, became more depersonalized and cryptic to outsiders, moving away from personal prose and focusing on cold descriptions (Perrault, 2013). Emotional discourses slowly but surely dissipated within the arcane, depersonalized language of academic journals and scientific societies[67] throughout the 19th and 20th centuries, a trend that has continued until today where the language of emotion is still considered taboo in much of the culture of science (Dror et al., 2016).

As universities sub-divided into ever-increasing smaller disciplines, and as demarcation appeared between what it meant to be a scientist and a non-scientist, science communication moved in to fill in the void left by science's departure from other cultural spaces (Hanauska, 2019, Perrault, 2013). This movement can be observed during the first half of the 19th century, whereby many of the science communication formats, such as public lectures, science biographies, popular science magazines, and the science fiction genre, among other things, standardized into forms that are still recognizable today (Hanauska, 2019; Holmes, 2008). A culture of contemporary science communication began to form around these science communication events, where new social meanings were constituted and from which new identities, such as the science journalist, the science populariser, and the science museumgoer, began to crystalize. In this emerging culture of science communication, the emotion category awe through the formations of the sublime and the wondrous found a new space to occupy.

4.3.2. Awe in the emerging culture of science communication

Throughout the late 18th and early 19th centuries, scientific work was to have a tremendous cultural impact on many artists from the Romantic period. They took inspiration in the discoveries and inventions of science to nurture their work with new categories, meanings, and metaphors (Holmes, 2008). Poetry interlaced with the vocabulary of science and the formations in which awe appears, such as the sublime, can be found in the works of Romantics, such as Samuel Taylor Coleridge, Lord Byron, and Percy Shelley. These writers took inspiration from the discoveries of science and the advances of technology to spread

as we do today" (2019, p. 586). However, there is some agreement that the appearance of contemporary science communication practices and products can be traced back to this period.

[67] This was more like a PR campaign as emotions continue to guide how science is practised (see Daston & Galison, 2007).

their credo of individualism, emotionality, and authenticity (Holmes, 2008). The influence of scientific themes in such works arguably reached its zenith in this period in Mary Shelley's novel *Frankenstein*. Inspired by researchers such as Italian scientist Luigi Aloisio Galvani, Shelley embedded her work both in the latest discussions about the role of electricity in the animation of bodies, and sublime imagery, as in the dramatic descriptions of the Swiss Alps, to single-handedly create a new fiction genre. *Frankenstein* remains one of the most enduring popular images of the intersection between science and the awe-inspiring (Economides, 2016; Holmes, 2008).

More importantly, while the culture of science was beginning to embark on its process of removing emotional language from its work, images of the sublime and the wondrous were very much present in the practices and products of early science communicators, who were now producing works about science for the general public. The stories of travels and voyages of scientists such as Joseph Banks and Alexander Von Humboldt were deeply steeped in the vocabulary of wonder and the sublime (Holmes, 2008; Wulf, 2015). These accounts enlarged the repertoire of signifiers associated with the ideas of the wonderous and the sublime in their descriptions of new worlds filled with fantastic scenes and objects that captured the imagination of the European crowds. The space discoveries of scientists such as William Hershel and the popularization of astronomy by people like Adam Walker, whose public presentations were deeply steeped in the sublime's romantic vocabularies, inspired new ways of feeling about the universe in an awe-inspired fashion (Golinski, 2017). Some of the first science popularization books written exclusively for non-specialist audiences, such as those of Mary Somerville, the earliest forms of science journalism and science biographies in the work of David Brewster, and the increasingly popular science lectures by people like Humphry Davy, were also responding to that cross-fertilization of vocabularies and meanings provided by the Romantic milieu (Holmes, 2008). The sublime and the wondrous were very much present when many contemporary science communication practices in the English-speaking world began[68].

The next generation of scientists, inventors, and journalists to popularise science, such as Charles Darwin and Michael Faraday, grew up deeply immersed in the poetry of Coleridge

[68] The foundation of the Royal Institution in the UK at the turn of the century (1799) has been used as a signpost for talking about an important period in early contemporary science communication practices (e.g., Holland & S. Miller, 1997).

and Shelley, the travelogues of Humboldt and Banks, and the lectures of Davy (Holmes, 2008, Wulf, 2015). They would come to use the language of the wonder of nature, the marvellous in the quotidian, and the power of the vast, to communicate science to general audiences (Bradley, 2011). Works such as Faraday's *Chemical History of a Candle* (part of the Royal Institution's Christmas lecture series) and Charles Darwin's *On the Origin of the Species* would expertly utilize the wonderous and the sublime formations through which awe-like emotions were represented to their audiences (Bradley, 2011; Holmes, 2008).

In parallel to these mostly British developments, in the early 19th century United States, human-made feats of science and engineering began to enter the sublime's semiotic economy in a formation that has come to be known as the *technological sublime* (Nye, 1994). The technological sublime had its echoes in much of the admiration towards science expressed by Romantic writers such as Coleridge and Shelley, on the one hand (Economides, 2016; Holmes, 2008), and the metaphorical triumph of reason over nature in Kant's sublime, on the other (Nye, 1994). As familiarity and domination rendered people's reaction to natural objects such as waterfalls, mountains, and oceans obsolete, attention moved to the next vast objects characterized as the "literalization of Kant's sublimity via technology" (Economides, 2016, p. 77). The railroad, the skyscraper, the dam, and many other forms of massive technological accomplishments were proof of reason's dominance over nature and a form of collective transcendence. A sense of awe, akin to admiration and marvel within the technological sublime applied to these human-made wonders, drew large crowds and constituted affective attachments to these objects. Jaw-dropping feats of engineering, such as early skyscrapers and tunnels, turned into sites of peregrination (Nye, 1994).

The technological sublime had other characteristics that separated it from its previous European iterations (i.e., rhetorical, natural, and Kantian). First, feelings of awe/admiration towards the figure of the 'genius' which were usually put in the artist, the scientist, or the politician, and that were common in the natural and the rhetorical sublime, were transferred to a new group of people who rapidly climbed the 19th century social hierarchy in the United States. The people with the practical skills to create these new technological marvels, the inventors and engineers, were the new geniuses, a source of all the awe-like admiration previously reserved for other people in the elite (Nye, 1994). Moreover, the stereotype of the lonesome, male, romantic vagrant, looking for a transcendent experience in the mountains, the ocean, or a faraway land, was renovated within the constraints set by the objects of sublime appreciation and the characteristics of US society. The sublime became a popular and collective experience in which people came together to witness the opening of a bridge or the inauguration of a railroad. Pomp and splendour in organized ceremonies became part of the sublime moment, whereby public displays of emotionally expressive behaviour were common (Nye, 1994). The technological sublime was there for the masses, who celebrated in the communal and expressive demonstration of man's dominion over nature. Another characteristic of the technological sublime discourse is its complete divorce from any metaphysical source (Nye, 1994). While some tried to tie the new human-made wonders to the presence of the divine, reason's power over nature actualized in the technological feats, pushed the sublime toward even more significant forms of secularization that were more and more divorced from its original religious frameworks (Nye, 1994). Moreover, familiarity rendered the objects of the technological sublime obsolete within the cultural logic of capitalism. Reason was to be continuously moving to bring about the next sublime object. With a hasty curiosity not dwelling long on one specific object, awe led to people longing for the future, where the next-big-thing was about to happen. Finally, this US version of the sublime was tagged to ideas about the country's manifest destiny, through which nationalistic ideologies could be represented and reproduced (Kessler, 2012; Nye, 1994; Sage, 2008). The move towards technological objects as indicators of the power of reason over nature, the changes in social hierarchies, the popularization of sublime objects, the public emotional displays, the secularization of the discourse, its focus on the future, and nationhood, changed the semiotic economy of the sublime experience in general, and the associations and meanings attached to awe. Within the formation of the technological sublime, feelings of awe as admiration and marvel brought about by new technological wonders and the genius of inventors and engineers, were now to be experienced collectively, openly, commonly, and loudly, and felt as an embodied representation of our species' dominion and mastery over the planet's resources and a hope for a godless future (Nye, 1994). As we shall see, expressions of the technological sublime that can be traced back to this romantic period continue to inform artistic representations of science and technology today, through other formations such as the nuclear sublime, the environmental sublime, and the astronomical sublime (e.g., Campbell, 2016; Kessler, 2012).

The continued specialization and professionalization of the scientific pursuit throughout the 19th century, and the appearance of science communication as a distinct cultural space, freed the culture of science from carrying emotional formations such as those on the wondrous and the sublime, while completely displacing those representations to the products and practices aimed at communicating science to non-specialist audiences. In Europe, romantic visions of the sublime and the wondrous were tethered to tales of exploration and discovery, whereby themes of beauty in nature and quotidian sensibilities around a sense of wonder surrounded awe's manifestations. On the other side of the Atlantic, by contrast, discourses of the sublime were put to use in the communication and popularization of new technological achievements, such as the railroad, the electric dam, and the skyscraper (Nye, 1994)[69]. From the first half of the 19th century until today, these two emotion discourses – the sublime and wondrous – and the many themes derived from their different iterations (e.g., rhetoric, natural, Kantian, technologic), have been part and parcel of the culture of science communication, giving meaning to how people represent awe within this cultural space, and socializing people into the knowledge from where they construct their representation of these emotions. Moreover, while the history and genealogy of these emotion discourses within science communication have not been written, it is easy to find them as recurring themes in the works of influential figures such as Albert Einstein (A. I. Miller, 1992), Harlow Shapley (Palmeri, 2012), Rachel Carson (Moore, 2005), Richard Feynman (A. G. Gross, 2018), and Carl Sagan (Helsing, 2016). In this last section, then, I turn to the few studies that have looked at the representation of awe through these discourses in current science communication.

4.3.3. Representations of awe in today's science communication

There is anecdotal evidence that representations of awe are common today in the culture of science communication (Kirby, 2015). Although a systematic analysis of these types of representations is yet to be carried out, they seem to be popular in science photography (Kessler, 2012), science television series (Campbell, 2016), general audience science books (A. G. Gross, 2018), science journalism (Perrault, 2013), children's literature (Bell, 2008) and stage science (Nadis, 2005). Most of the research that has been carried out on these emotions has focused on space sciences (Campbell, 2016; Helsing, 2016; Kessler, 2012), though a few studies have looked at their role in other areas, such as biology (e.g., Turney,

[69] A version of this sentence appears in (Silva Luna & Bering, 2020, p. 8)

2004), ecology (e.g., Moore, 2005; Perrault, 2013) and geology (D. P. Dixon et al., 2012). For the most part, these are qualitative studies using a range of literary (e.g., A. G. Gross, 2018; Turney, 2004) and rhetorical (e.g., Fahnestock, 1986; Perrault, 2013) techniques to analyse texts that convey scientific knowledge to non-specialist audiences. Some have focused on the formation of the sublime (e.g., A. G. Gross, 2018; Kessler, 2012; Turney, 2004), while others have looked mainly at the representation of the wondrous (e.g., Helsing, 2016; Sideris, 2017). Together, this limited empirical body of work shows some evidence of the value of awe in science communication, and the variety of forms and functions it takes in this cultural space.[70]

4.3.3.1. The sublime in contemporary science communication

While the technological sublime celebrated industrial accomplishments (Nye, 1994) and the natural sublime focused on natural objects investigated by science (A. G. Gross, 2018), both shared an elevation of human reason and its conquering of nature, placing the work of scientists and engineers as sources of admiration, marvel, and awe. These expressions of the sublime continue to inform artistic representations of science and technology today (e.g., Campbell, 2016; Kessler, 2012). However, over the past century, several new versions of this formation began to appear in response to the rapidly changing technological, environmental, and social conditions through the 20th and early 21st centuries. This is the case, for example, of the *nuclear*, *environmental*, and *astronomic sublime*.

The incalculable loss of the effects of two World Wars, the death camps, and the carpet bombings of large cities, began a disenchantment with the sense of optimism concealed in the technological sublime, transforming the formation's affective tone and form (Nye, 1994; Ray, 2005). Objects and people through which the discourse of the sublime moved under the logic of admiration and marvel, were now overshadowed by two technologies from which "nature and human existence ceased to be pre-given and became contingent" (Nye, 1994, p. 228). The combination of the rocket technology perfected by the Nazis, and the atomic bomb created from the Manhattan Project, led to the development of intercontinental ballistic missiles (ICBM) with nuclear warheads, which the United States and the Soviet Union began mass-producing from the 1950s as a result of their decades-long détente. From the choices of

[70] A version of this paragraph appears in (Silva Luna & Bering, 2020, p. 3)

a few people, the human species could now go extinct. The possibility of collective uplifting and transcendence through technological achievements was undercut by a new emotional palette. Under this new structure of feeling (R. Williams, 2009), terror and anxiety prevailed as a result of living in a world that could not be taken for granted, or a so-called death-world[71] (Nye, 1994, p. 228). Under these circumstances, a new form of the sublime appeared.

The language of the sublime, with its descriptions of power, vastness, its logic of conquer, its narrative of ravishment and transport, and its emotional vocabulary of astonishment, terror, and awe, permeated the descriptions written by many of the military, scientific, and civilian personnel who witnessed the atomic blasts carried out until the 1960s (Nye, 1994). While a few witnesses were transfixed in admiration and celebrated the event as a triumph of humans over nature – remnants of the discourse of the technological sublime (C. J. Dekker, 2014) – a sense of terror and dread pervaded many of the descriptions of the power of the atomic bomb (Nye, 1994, Ray, 2005). This new discourse of the sublime, labelled by various authors as the atomic or nuclear sublime (Dekker, 2014; Hales, 1991; Nye, 1994; Wilson, 1991), returned to the vocabulary of terror and dread captured by the original religious meaning of the word awe. This emotion vocabulary became the primary tool through which the incommensurability, transfixion, incomprehension, and quasi-religious experience[72] of the atomic bomb, could be represented affectively.

Moreover, the nuclear sublime brought an end to the era when technological achievements were unquestionably celebrated in the United States. While Luddite movements and visions of science-gone-wrong, such as Mary Shelley *Frankenstein*, were somewhat common in the United Kingdom and continental Europe, the United States had kept for the most part a general enthusiasm for the developments of science and technology, from the arrival of the railroad in the 19th century to the New York World's Fair in 1939 (Nye, 1994). With the atomic bomb, however, the feeling of security, the sense of collective achievement, and the esteem towards scientists, inventors, and engineers, that characterised the technological sublime, began to erode. An oscillation and ambivalence appear in which the public moved between admiration of scientific success in events such as the triumphs of space exploration,

[71] Gene Ray (2005) described this death-world as follows: "After Hiroshima, we inhabit a world immeasurably more threatening, a world threatened in fact to the very extreme and in this sense worthy of deep dread and even deeper denial" (p. 92).

[72] The semi-apocryphal story of the head of the Manhattan project citing the famous passage of the Bhagavad Gitta: "I am become death, the destroyer of worlds" comes to mind (see Dekker, 2014; Nye, 1994)

and the existential fear and terror that science and technology wrought (Nye, 1994, p. 255). And while the atomic bomb represents the ultimate existential threat, representations of global biohazard risks, dangerous artificial intelligence, nanorobots grey-gooing the planet, particle experiments gone-wrong, and other potentially cataclysmic examples of dangerous technoscience, all contain elements of the nuclear sublime's affective tones and its other semiotic characteristics.

The nuclear sublime's negative affective language and its focus on the excesses of science are passed on to yet another iteration of the sublime, the so-called ecological or environmental sublime (Economides, 2016; Hitt, 1999; Rozelle, 2006). As humans have become aware of the enormity of the ecologic disaster that they have unleashed on the planet, the sublime's vocabulary for humanity's achievements in the technological sublime and pristine mountains and oceans in Burkean descriptions of the natural sublime has receded. The representation of showers of acid rain, climate change enhanced hurricanes, towering wastelands, massive fires consuming everything in their path, collapsing natural habitats, islands of non-biodegradable plastic, and ongoing mass extinction, signalled our lack of control over the forces that we had unleashed on our planet through the use of those same technologies we previously marvelled over. As with the nuclear sublime, awe's social meanings turn towards the horror and dread for humanity's destructive capacity (Economides, 2016; Rozelle, 2006). However, while the signifiers of emotions in the nuclear sublime focused on specific technologies made for destruction, where blame could be rightly directed at specific governments or individuals, the source of the environmental sublime cannot be so obviously linked to any one particular object or actor. Everyone (some more than others) is a participant in the new sublime objects (Economides, 2016)[73].

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[73] Some authors such as Rozelle and Hitt have argued that the environmental sublime can bring about increased awareness of the environment (Rozelle, 2006) or a certain humility towards nature (Hitt, 1999) that could engage people and generate momentum towards political action. However, according to Cronon (1989), Economides (2016) and others, the discourse of the sublime as a possible way of political action for addressing our environmental crisis is problematic. For these authors, the environmental sublime both displaces blame and reinforces our beliefs in the power of reason. As a result, massive feats of engineering invoking the technological sublime that are business-as-usual, are seen by many as the only way to tackle the current environmental crisis (Economides, 2016). The Romantic authors used the aesthetic of the sublime to ignore many of the political and social difficulties of the late 18th and early 19th centuries (Weiskel, 1986). Similarly, representations of the current environmental problems as sublime can displace the blame as something beyond the individual's control, leading to apathy or denial. Apathy and denial arise from the sense of disconnectedness that the sublime brings to representations of the current environmental crisis, opening up the political and economic space for solutions that depend on vast technological responses. These engineering solutions to the environmental crisis are the ultimate form of a technological sublime in which nature is thoroughly subjugated to human necessity (Economides, 2016). Awe-as-terror for the current environmental catastrophe works within the discourse of the sublime as an instrument for moving people away from a reflection that would point directly into their own behaviours as the source of sublimity. The emotions represented within the discourse of the environmental sublime close the road for political action as they move people away from confronting its source in themselves while advocating for a correspondingly enormous technological fix within a technological sublime that could lead to several unintended consequences (Economides, 2016).

In an analysis of the environmental sublime, Economides (2016) describes a new emotional focus that seems to be forming around it, which can potentially be changing the social meanings of awe within this formation. The environmental catastrophe represents the 'death of nature', the loss of that 'other' that needs to be conquered for the transcendent moment of the original sublime to occur (Economides, 2016, p. 119). The environmental sublime finds itself at odds with the reality of loss from which mourning arises in the form of sadness and melancholy that permeates the discursive formation. Sadness and melancholy paralyse rather than drive action, and in this semiotic economy, awe arrives, potentially, at a new gloomy social meaning. An example of the kind of paralysis found in the discourse of the environmental sublime, and one charged with melancholic affect, is Economides's (2016) analysis of people's relation to the ocean. Once a source of admiration and fear for sailors and artists alike, events such as the death of coralline environments, the collapse of animal colonies, and floating country-size gyres of garbage, makes the sea a signifier of humanity's recklessness and destruction, evoking a common emotional reaction of combined dread, culpability, and sadness. Within these semantic networks, awe is suffused with anxiety and hopelessness akin to the dread in the terror of the nuclear sublime, but with a general sense of sorrow that makes people look away instead of confronting the reality of the environmental catastrophe.

The discourses and aesthetics of the nuclear and the environmental sublime represent only a small portion of the formations used in the communication of science today. More common uses rehash romantic notions of the natural sublime; with the most popular being those associated with space science, in what has been called the astronomical sublime (Kessler, 2012). Looking at the different aesthetic choices made by creators of different astronomy television programmes, Campbell (2016) identified how stylistic choices, such as the usage of 'candy apple neon' colour pallets for the shows, the magisterial gaze (the "Olympian perspective"; see Sage, 2008), and the usage of a 'grand tour' narrative, all reference the natural sublime through their intertextual associations. These strategies by science documentary filmmakers, Campbell argues, are aimed not only at communicating knowledge, but instrumentalized to work "as vehicles for the representation of science as sublime" (Campbell, 2016, p. 187). As such, these endeavours are represented as having transcendental significance.

Similarly, Kessler (2012) argues that the way public images of the Hubble Space Telescope are created reflects a long tradition of representations in astronomy tracing back to the sublime aesthetics of the Romantic period. The use of "saturated colour, high contrast, and rich detail as well as majestic compositions" (Kessler, 2012, p. 4) in space images are reminiscent of late 19th and early 20th century landscape images of the North American West. In both cases, the treatment of shape, colour, size, and scale is meant to elicit a sense of awe and wonder. The goal of these aesthetic choices "lulls the viewer into believing human senses can perceive the cosmos" (Kessler, 2012, p. 67) and signify the power of science to capture nature.

Astronomers, photographers, and documentary film producers are attaching new forms of representation through the sublime to an already pre-established emotional script. Whereas the Romantics ascribed this ability to mountains, oceans, and waterfalls, astronomy communicators, through their Hubble images and space documentaries, enlarge the representational repertoire, introducing images of distant galaxies, nebulae, and grand tours of the cosmos. In that sense, the astronomic sublime can perhaps best be conceptualized as an extension or continuation of Romantic versions of the sublime (Kessler, 2012).

The astronomical sublime also serves as a reinforcement of belief systems that are more centred in contemporary representations of science. Notably, the sublime aims to reaffirm the power of science over nature (Campbell, 2016; Kessler, 2012; Sideris, 2017)[74], beliefs that in their more extreme version amount to forms of scientism (Owen, 2020). Kessler (2012) also suggests how the aesthetics of the astronomic sublime have been associated with the ideology of manifest destiny very much present in the US's frontier politics. According to Sage (2008), the astronomical images such as those of the moon landings conjure the sublime landscapes of the frontier images that have been so important in the articulation of US national identity. The emotions that these evoke, according to the author, are then central to the constitution of how people from the United States view themselves and their role in the world. The motifs, techniques, and codes used in astronomical images that allude to the

[74] Sideris (2017) argues this is a form of wonder, yet her description is much closer to a version of the sublime.

sublime are instrumentalising their emotional content to perpetuate worldviews, such as scientism and nationalism, that are localised in contemporary realities.

Scholars and critics have identified yet further contemporary awe-based formations that allude to sublime aesthetics and discourses in the communication of science. These include Turney's (2004) *abstract sublime*, Mosco's (2005) *digital sublime*, or the many other scientific sublimes described by A. G. Gross (2018) (e.g., *biophilic sublime*, *polymath sublime*, etc.). Although a thorough discussion of each such iteration is beyond the scope of this chapter, it is important to recognise the importance that the sublime continues to exert in science communication, with each formation adding new sets of social representations to emotion categories such as awe. With that in mind, I turn my attention to the appearance of formations related to the wondrous, a lens through which awe is often used in contemporary science communication.

4.3.3.2. The wonderous in contemporary science communication

At least two versions of the discursive and aesthetic formations around the wondrous have continued to manifest differently throughout the 19th and 20th centuries in the communication of science. The first of these refers to a motivation towards investigation and exploration, which should be extinguished through these practices, while the second discourse focuses on the contemplation, appreciation, and the continued sustenance of its affective characteristics (Rubenstein, 2011; Vasalou, 2015). In contrast to the themes of vastness and transcendence in the sublime, the wondrous manifests in forms of attention and engagement towards the world that can generate curiosity on the one hand or the defamiliarization of any objects in its line of sight on the other. The former views awe as an instrument for observation and enquiry, while the latter works as a general "sense of wonder", whereby themes around the quotidian, the beautiful, the small, and the pastoral allow everyday objects to potentially become awe-inspiring. While these different formations of the wonderous have been described through the literary works of authors such as Henry James and James Joyce (Abrams, 1971; Vasalou, 2015) and philosophical works by Heidegger, Wittgenstein, and Merleau-Ponty (see Economides, 2016), they also appear in the works of popular science communicators, such as Richard Dawkins, Rachel Carson, and Carl Sagan (e.g., Helsing, 2016; Moore, 2005; Sideris, 2017).

While recognizing the many ways in which wonder has been used in the communication of science, Sideris (2017, p. 16) contrasts what she calls “inappropriate forms of wonder” with its “wholesome varieties”. The author identifies the former variety in the work of authors such as Richard Dawkins, who describes wonder as a source of curiosity that leads towards scientific investigation: an engine that motivates the intellect towards dispelling the mysteries of the world and displaces one’s affective engagement towards a novel source. This version of wonder is reminiscent of the previously described instrumental wonder of Bacon and Descartes that works as a ‘sensibility of enquiry’ (Daston & Park, 1998; Vasalou, 2015). However, while previous writers were uncertain of wonder, afraid of its excesses and always aimed at dispelling it, Dawkins and others have argued for a continued revelling in this emotion through scientific knowledge (Sideris, 2017). Within this formation, scientific knowledge and scientists become the ultimate purveyors of awe, setting the basis for elaborating scientific cosmologies that consecrate science into a new global myth in the works of authors such as E. O. Wilson. Other authors have observed this tendency of discourses around wonder to reference “the amazing powers and secrets of nature or of the breakthroughs and accomplishments of the scientists themselves” (Fahnestock, 1986, p. 279) and boost science’s image as a ‘glorious’ endeavour – an image that potentially harms science, both raising the publics’ expectations and conferring authority to pseudo-scientists[75] (Perrault, 2013, p. 55-56).

Another exponent of the wonderous, Rachel Carson’s work is seen as embodying the ideas around a ‘sense of wonder’ that can defamiliarize the quotidian, and revel in the beautiful and the mysterious (Moore, 2005; Sideris, 2017). By contrast to the overall awed childlike response towards objects big and small in previous iterations of the wondrous formation, Carson’s ‘sense of wonder’ is something to cultivate by closing the “distance between ‘this is wonderful’ and ‘this must remain’” (Moore, 2005, p. 30). This evolves into an ethics of caring and compassion towards the non-human world that contrast with the logic of domination and exploitation present in other formations in which awe participates, such as the natural and technological sublime. The connection to the natural world, motivation to protect it, appreciation for the mystery of life, and other such environmental themes give new colouration to the emotion category ‘awe’ within this wondrous formation.

[75] Perrault (2013) gives the example of Andrew Wakefield, who used the image of a persecuted Galileo to portray himself and his cause against vaccines.

Overall, this taxonomy of the contemporary formations around the sublime and the wondrous in science communication is but a very limited attempt at describing the complex ways in which emotion categories such as awe appear in this cultural space, masking how these have been intertwined, experimented over, and utilized by the many practitioners who have represented these categories in their work. One case in point is the work of Carl Sagan, whose quasi-theological view of science as the ultimate source of awe and wonder, as well as his frequent use of vastness and scale as rhetorical tools (particularly in his *Cosmos* television series) reflect both the instrumental use of wonder and themes related to the sublime to highlight the power of science and human reason over nature (Lessl, 1985; Sideris, 2017). However, Sagan's aesthetic sensibilities around the beautiful, his ethical commitments to denounce nuclear armaments, and his defence for humility in the face of human hubris, present different themes around the wondrous (Helsing, 2016; Sagan, 1997) that contrast with the approach of other popular science communicators such as Dawkins. Just as with artists in the Romantic era, science communicators are now taking from different discursive formations to create new vocabularies, expressing different forms of affective experiences around awe and wonder, and giving these emotions whole new sets of forms and functions. Whether this emotion is conveyed through images of large objects such as the Apollo program (Nye, 1994), galaxies (Kessler, 2012), the Large Hadron Collider (A. G. Gross, 2018), or the small, beautiful, and picturesque, such as flowers or the sky (Moore, 2005), or whether it functions to captivate audiences (Fahnestock, 1986), generate escapism (Jeffries, 2003), frame the sciences as sublime (Campbell, 2016), communicate ethical and aesthetic concerns (Helsing, 2016), reframe people's relation to the natural world (Moore, 2005), make it into a quasi-religion (Sideris, 2017), or reinforce national identity (Nye, 1994; Sage, 2008), the awe represented in contemporary science communication is continuously mixing and giving these categories new social meanings, all of which are historically contingent and culturally situated in the products and practices of their specific place and time.[76]

4.4. Conclusion

The variety of social meanings through which the emotion category awe is represented results from an assortment of historical circumstances and cultural formations, tying this emotion to the shared meanings that constitute the culture of English speakers who use this word. In this

[76] A version of this paragraph appears in (Silva Luna & Bering, 2020, p. 7)

chapter, I have identified some of those social meanings by outlining a tentative history of this emotion category, through the formations of the sublime and the wonderous. The original meaning of awe as terror was first complemented by ideas about admiration, and later by those of marvel and wonder in the interaction of these formations. Associations of this emotion to natural objects, quotidian and familiar spaces, human-made inventions, or the abilities of individuals, are also the result of historical contingencies that displaced descriptions of emotional reactions initially reserved for the figure of the godhead. Themes for awe such as elevation, curiosity, humility, gratitude, transcendence, terror, and beauty, have all hinged on haphazard factors inscribed in the social, political, cultural, economic, and technological developments of the English language culture through and over large stretches of time. I have attempted to trace a few of those developments through the discourses and aesthetics of the sublime and the wondrous, briefly focusing my attention to the Romantic period as a semiotic "laboratory", in which awe acquired many of the meanings still associated with it today and from where much of English-speaking early science communicators drew inspiration.

I have also outlined the complex sociocultural processes by which the foregoing linguistic conventions became part of science communication, a culture in which people talk about science to non-specialist audiences. I have argued that, although Western science has had its associations with wonder since its inception as a feeling conducive to scientific investigation, it was in its encounter with the sublime and the appearance of contemporary science communication in the Romantic era that much of the senses and connotations now related with this emotion became consolidated in this cultural space. Moreover, I looked beyond the Romantic era and showed how some of the more recent iterations of this emotion category have been inscribed in contemporary versions of the sublime and the wondrous, such as the technological sublime, the nuclear sublime, and the environmental sense of wonder.

This literature review is only a tentative effort to develop a historical and taxonomic framework to think of the varieties of social meanings that this emotion category has today in the communication of science, with all its limitations and defects. Contextualizing some of the varieties of awe in time and place, however, allows me to shed any pretence of universality and describe how contemporary both mental and social representations of this emotion are deeply situated in this cultural milieu, setting the stage for the discussion of the studies in the following chapters. Nonetheless, future studies can use this modest history of the category awe to explore the different histories that these representational varieties have taken and explore other contexts outside the United States and the United Kingdom which have been the focus of this chapter.

Chapter five - The social representation of awe in picture book biographies of scientists

5. Introduction

Cultures promote the emotions they value through their various products and practices (Mesquita et al., 2017). More importantly, an emotion category will take a variety of forms and functions across cultures and within them (Barrett et al., 2014). The content of an emotion category will be a function of a culture's values, beliefs, norms, goals, and worldviews, which have developed over time as a result of their many historical contingencies (see Boddice, 2018, 2019).

As mentioned, previous studies have described the historical presence of social representations of awe in different cultural artefacts from the culture of science communication. This emotion shows up in contemporary popular science media such as non-fiction books, TV documentaries, and science photography (e.g., Campbell, 2016; A.G. Gross, 2018; Kessler, 2012; Sideris, 2017). Such work suggests that the emotion category of awe is valued in this cultural space and thus is represented with a higher incidence in its practices and products, an abundance that some scholars have pointed out (Kirby, 2015). No study, however, has tested empirically whether this is the case.

Moreover, the few works that observe the presence of awe in the communication of science describe a variety of types in the forms and functions that this emotion takes (e.g., Nye, 1994; Sideris, 2017). For example, awe is represented in relation to a variety of different objects (e.g., galaxies, the Large Hadron Collider, experiences in nature) and settings (e.g., planetariums, museums, outdoors, science documentaries) (e.g., Kessler, 2012; Moore, 2005). Moreover, this emotion has been described as having a myriad of functions in science communication (see chapters 3 and 4), including charming different publics (Fahnestock, 1986), producing a distraction (Jeffries, 2003), framing science as sublime (Campbell, 2016), constructing identities in relation to the natural world (Moore, 2005), consecrating science (Sideris, 2017), and reinforcing pride in one's nation (Nye, 1994)[77]. Research in this area suggests a multiplicity of awe types in this cultural space standing for the various mandates

[77] A version of this paragraph appears in (Silva Luna & Bering, 2020, p. 7).

that circulate within it. None of these studies, however, has singled out the emotion category awe and catalogued the variety of forms and functions it assumes.

In this chapter, I present the results of three studies that evaluate through content analysis the incidence and content of representations of awe in one type of cultural artefact: picture books. Picture books in general are an excellent tool to evaluate the value and quality of an emotion in a culture. These have widespread usage in industrialized settings as artefacts through which parents and educators promote the child's cognitive development and socialization into a culture (e.g., Kümmerling-Meibauer & Meibauer, 2013, 2015; Nikolajeva & Scott, 2013). Most importantly, picture books both mediate the development and socialization of emotions (e.g., Garner & Parker, 2018; S. L. Gordon, 1989; Tsai et al., 2007) and are one of a child's earliest points of contact with science (e.g., Brunner, 2019; Dagher & Ford, 2005; Kelly, 2018; Schroeder et al., 2009).

Multiple studies have compared the prevalence and content of emotion across cultures using picture books (e.g., Boiger et al., 2013; Garner & Parker, 2018; Tsai et al., 2007; Vander Wege et al., 2014). There are also many studies that have looked at how different objects and people are represented in science picture books (e.g., Brunner & Abd-El-Khalick, 2017; Dagher & Ford, 2005; Kelly, 2018; Owens, 2009). However, no study has looked into how emotions are represented in science picture books. Considering the importance of picture books in the acculturation of a child and the socialization of their emotions, such artefacts have significant potential as an empirical tool for assessing the representation of particular emotions in cultural context. This study is the first to examine how awe occurs in the cultural space of science communication, using science picture books as a real-world gauge of its depiction.

I begin this chapter with a brief methodological overview of content analysis and a literature review which summarizes some of the relevant literature on emotions and picture books. Then I outline the preparation stage for the three studies, introducing the object of study, describing the sampling processes, and discussing ethical issues. The next three sections sequentially describe each of the studies to then conclude with an overall discussion of the findings, limitations, and possible future directions. Following my conceptualization of awe and its role in this cultural space (see chapter 3), I expected to find that awe would be more commonly represented in the science picture books, as they are artefacts of the culture of science communication. Moreover, I anticipated finding different types of awe represented in the science picture books; representations that are qualitatively different from those in the picture books produced outside this culture.

5.1. Methodological overview

Content analysis is a series of “research techniques for making replicable and valid inferences from texts to the contexts of their use” (Krippendorff, 2004, p. 18), and which were originally developed in the early 20th century to analyse messages in both newspapers and political propaganda. Broadly speaking there are two types of content analysis: quantitative and qualitative content analysis. Quantitative content analysis is, for the most part, concerned with capturing the incidence of keywords or content using a dictionary or standard against which counts can be made. These coding schemes are usually theory derived and are prepared before the coding. As such, the various versions of quantitative content analysis emphasize solving issues of reliability and validity, with practices such as creating mutually exclusive categories and bringing in second coders to assess intercoder agreement (Krippendorff, 2004; Neuendorf, 2017). By contrast, *qualitative content analysis (QCA)* focuses on confirming or providing new insights on social phenomena (Hsieh & Shannon, 2005; Schreier, 2012) by combining both top-down and bottom-up categories to systematically describe materials using a coding frame. While QCA also regards issues of validity and reliability, its focus is on trustworthiness, which refers to issues such as rigorously proceeding through the different research phases and accurately reporting these (Elo et al., 2014; Schreier, 2012).

A special kind of quantitative content analysis is textual content analysis. While this was traditionally done manually by coders, over the last couple of decades it has been increasingly performed by computers, with an ever-increasing degree of sophistication (Neuendorf, 2017). As a result, such an approach has evolved into a vast array of computer-assisted techniques to evaluate written texts, including word embeddings, sentiment analysis, and big data. Together, these various fields have converged into one unified discipline called text analytics or text data mining (TDM) (Anandarajan et al., 2019).

5.2. Literature review

Various studies have used quantitative content analysis to compare how often emotions are represented in different types of picture books. Tsai et al. (2007) coded emotional expressions, smiles, and arousal levels in 20 US and Taiwanese picture books to compare the representation of ideal affect. Similarly, Vander Wege et al. (2014), used a code for distinct emotions, intensity of expression, and social context on 10 US, 10 Romanian, and 10 Turkish picture books searching for differences in valence, intensity, and frequency in emotion representations. Finally, Boiger et al. (2013) coded for instances of anger and shame in 19 Belgian and 19 US picture books, comparing how these emotions were represented in artefacts from these two cultures. Other studies have used quantitative content analysis to study emotions in picture books, focusing on, for example, differences in the representations of emotion in different genders (e.g., Tepper & Cassidy, 1999), how emotions are portrayed in picture books overall (e.g., Garner & Parker, 2018), and how different emotions are portrayed in European-American vs Mexican-American books in the United States (Sanders et al., 2018). Overall, these studies have consistently observed differences in the representation of emotions across cultures.

Moreover, content analysis has been used to look at how science is communicated in picture books. All these studies have been done in the field of science education and have focused on representations of science and scientists. Dagher and Ford (2005) studied the portrayal of scientists in twelve picture book biographies. Similarly, Rawson and McCool (2014), and more recently Farland-Smith et al. (2017), coded representations of scientists using the Draw-A-Scientist Test Checklist (DAST-C), assessing stereotypical elements of their portrayal. Another important study coded for different elements of the Nature of Science (NOS) in a sample of 44 picture books (Ford, 2006). Similar studies coding for elements of the NOS in picture books have been done more recently (e.g., Brunner & Abd-El-Khalick, 2017; Kelly, 2018). These studies have detailed how many science picture books in the market today represent science using stereotypes that don’t correspond to the realities of how it is done (e.g., Brunner & Abd-El-Khalick, 2017) and scientists using clichéd tropes such as that of the old white man wearing a lab coat (e.g., Rawson & McCool, 2014).

While all these studies have used different forms of content analysis to examine aspects of picture books in relation to the depictions of emotions, science and scientists, no study to date has explored how emotions are represented in picture books aimed to communicate science.

5.3. Preparation stage

In this section, I present the preparation phase shared by the three studies. This includes the definition of the object of study, the sampling, and a brief discussion of ethical issues that arose during these studies.

5.3.1. Definition of the object of study

Although there is no agreed upon definition of a picture book, most characterizations concur that these cultural artefacts are a form of multimodal texts in which visual and verbal elements interact to convey meaning (e.g., Darigan et al., 2002; Nikolajeva & Scott, 2013; Nodelman, 1988). Although broad, this definition covers the many perspectives from which picture books are used and studied. Whether treated as an educational tool (e.g., Kümmerling-Meibauer & Meibauer, 2015), an art form (e.g., Nikolajeva & Scott, 2013), an ideological artefact (e.g., Stephens, 1992), or a book layout (e.g., Darigan et al., 2002), there is an important tradition of studying culture through the lens of these cultural artefacts.

Picture books in which the informational content refers to a "specialized way of talking about the world" (Lemke, 1990, p. xi, cited in Donovan & Smolkin 2002, p. 503) identified as "science" can be thought of as science picture books. There are different ways of classifying science picture books. For example, Kelly (2018) groups these in relation to their scientific field: earth and space sciences, engineering, technology, and applications of science, and physical sciences. These are also classified by their genre[78]. Using genre as a category, Donovan and Smolkin (2002) classified science picture books as storybooks, narrative informational texts, non-narrative informational texts, or dual-purpose texts[79]. Other

[78] By genres, I am referring to the social semiotic tradition which identifies ways of organizing texts using certain rules with specific goals within a social and cultural space (Donovan & Smolkin, 2002).
[79] Donovan and Smolkin (2002) define storybooks as those in which characters move through time in a sequence of events (i.e., plot) within a structure (i.e., story grammar) and include basic elements, such as a setting, an initiating conflict, and a resolution of this. The narrative-informational texts also include a series of events set so as to make factual claims. These usually refer to those science picture books that describe processes of nature such as life cycles. Non-narrative informational texts are those where the unifying characteristic is not sequentiality but rather an exercise in co-classification around a topic. These are perhaps the most common type of science picture books and include concept books, picture encyclopaedias, and how-to books. Finally, dual-purpose texts refer to texts that combine elements of narrative and non-narrative. The main text in a dual-purpose science picture book is usually told within the traditional narrative format.

classification schemes based on genre collapse the category of dual texts and narrative informational books into one category usually labelled as hybrid (Pappas, 2006) or combination (Schroeder et al., 2009) texts. Many science picture books exist somewhere along a continuum of hybridity with purely informational books on one end, and purely narrative books on the other (e.g., Ford, 2006; Pappas, 2006; Schroeder et al., 2009).

A particular genre of hybrid picture books are picture book biographies. In its most basic conceptualization, biographies represent the life and times of one or multiple individuals, many times told from cradle to grave (Hendrick, 1998; Muurlink & McAllister, 2015). Adapting this definition to the purpose of this study, I define science picture book biographies as books that represent through both written text and visual information the life of one person or many people related to science. Picture book biographies are hybrid texts that include powerful stories and images aimed at captivating and inspiring children (Darigan et al., 2002). As Bader (2013, p. 18) points out, picture book biographies "at their best" can "rivet attention, convey emotion, [and] imprint a moment". As hybrid texts, the chance of encountering representations of affective categories in picture book biographies is much higher than in the dry descriptions of informational texts. Importantly, evidence suggests that books that have narratives are preferred both by children and adults when choosing picture books (Bergman Deitcher et al., 2019; Wagner, 2017). Because all picture book biographies include some sort of narratives and these convey emotions, I chose this kind of book as the object of my study.

Science picture book biographies have been recognized as an important resource for educators (Kelly, 2018), helping students to develop a comprehensive view of science and scientists (Sharkawy, 2009, 2012). However, research on this particular kind of book is scarce, with the few studies in this area showing that these present a rather limited and stereotypical view of science in general (Dagher & Ford, 2005) and fail to convey inclusive representations of gender (Owens, 2009), among other issues.

However, these books usually make use of features such as captions, boxes, and diagrams on the margins and the author's note, foreword, and other aspects of the peritext to present informational content (Donovan & Smolkin, 2002).

5.3.2. Sampling

While some studies on picture and science trade books for children have used a random selection of books from libraries (Ford, 2006), I followed the lead of previous authors who have used convenience sampling (e.g., Abd-El-Khalick, 2002; Kelly, 2018; Owens, 2009).[80] Some of these investigators chose their samples from lists of award-winning trade books for children. The rationale for selecting picture books from such lists has been three-fold. First, these awards are given based on excellence by highly recognized professional organizations such as the National Science Teachers' Association[81] (NSTA) and the American Library Association (ALA)[82], meaning that the books on these lists represent the most preeminent books of their kind and are used by educators and librarians to support academic excellence (Crowther et al., 2005). I assume that award-winning picture books have the finest representations of the cultural milieu in which these are produced. Second, book awards in the United States function as market signals that increase the consumption of a product (Dekker & de Jong, 2017). In the case of children's books, parents, schools, and libraries guide their consumption decisions on the information provided by these awards (e.g., Bang-Jensen, 2010; Wagner, 2017). Publishers stick big labels to the front cover of the books announcing the awards these have received, while websites such as Amazon highlight in their book descriptions the importance of these honours. And although there are no precise data comparing sales numbers of award-winning and non-award-winning picture books, a small report that looked at library holdings in the Worldcat index found that books that received the Outstanding Science Trade Books for Children award were the most widely available in libraries around the world (Owens, 2009). Thus, it is a reasonable assumption to surmise that award-winning picture books are bought more by parents, libraries, and schools, than are those that do not win such awards. Third, because these are some of the most popular books, the process of finding and acquiring them in Aotearoa New Zealand was considerably easier.

[80] Accurate publishing figures on picture books in general, science picture books in particular, and picture book biographies of scientists are very hard to come by. In the 1990s, around 5,000 picture books were being published every year in the US alone (Darigan et al., 2002). While there is no database containing the total population of science picture book biographies, a study that took a sample of science picture books from the winners of the Outstanding Science Trade Books (OSTB) given by the National Science Teachers' Association observed that science biographies made up about 14% of the total of the sample (Kelly, 2018). Whether this is an accurate representation of the proportion of science picture book biographies in the market is unclear, however.

[81] Founded in 1944 the National Science Teachers' Association is the largest and most recognized science teacher group in the United States with more than 57,000 members (National Science Teachers' Association, 2020).

[82] The American Library Association is the oldest library association in the world, promoting libraries and library education since 1876. While based in the United States, it provides support to members from many countries around the world (Association for Library Service to Children, 2020).

The recognition of their excellence, their widespread consumption, and the ease of acquiring them were the main reasons I chose award-winning picture books.

I then chose a sample of picture books from the lists of perhaps the two most prestigious awards given yearly to the best trade books for children in the United States. These are the Notable Children's Books (NCB)[83] and the Outstanding Science Trade Book for Children (OSTB)[84]. These are both bulk awards given every year to dozens of books that target the same audience – children K-12 (Association for Library Service to Children, 2020; National Science Teachers' Association, 2020). Being bulk awards of children's literature means that they capture a large cross-section of the many books produced each year in various formats and genres. This includes many picture book biographies, the final target of the sampling process. The similar quantity of books selected every year and the same age target makes these samples comparable. Moreover, previous studies looking at different forms of representations in children's literature have used both the NCB (e.g., Gooden & Gooden, 2001) and the OSTB (e.g., Kelly, 2018) for sampling purposes. Finally, it is important to highlight that the NSTA is only given to books that "reflect current scientific knowledge" and "when appropriate, advances the Nature of Science (NOS), scientific thinking, and has general compatibility with book content and the Next Generation Science Standards (NGSS)" (National Science Teachers' Association, 2020). These selection benchmarks show a high-quality standard for the winners in relation to the science content of the books. To sum up, as a result of the similarities in size, target audience, reputation, their use in previous research, and the scientific criteria used to judge NSTA books, I selected these two lists of award-winning trade books for children as the starting point in my sampling process.

The timeframe for selecting the books was between 2000 and 2018. Considering that I am narrowing down the total number of books by focusing on one particular book genre (i.e., picture book biographies), I wanted to have a large cross-section of books in the initial selection so that there would be enough books in the final sample. Given that around 50

[83] The NCB is awarded by the Association for Library Services to Children (ALSC) which is a subdivision of the ALA. This bulk award has been given every year since 1940 to over 70 books a year, including the winners of the Belpré, Caldecott, and Newbery medals (Association for Library Service to Children, 2020). The list includes books written for children ages K-12 in various formats (e.g., chapter books, graphic novels, picture books), and genres (fiction, non-fiction, expository).
[84] The OSTB is given yearly to over 40 books since 1973 by the American National Science Teachers' Association (NSTA), in association with the Children's Book Council (National Science Teachers' Association, 2020). This bulk award highlights the best trade science children's books in the US market for children grades K to 12, of which many end up becoming bestsellers.

books receive these awards every year, I found that a starting selection of about 1,800 books was appropriate for this research.

Having defined the source of the books and timeframe, I created a spreadsheet that included all the winners of the OSTB and the NCB of the previous two decades (2000-2018) using the websites of the National Science Teachers Association (National Science Teachers' Association, 2020) and the American Library Association (Association for Library Service to Children, 2020). However, both lists include all sorts of formats and genres of books for children. I then narrowed the sample only to picture book biographies. This left me with 139 NCB and 71 OSTB winners. Many of the biographies, however, were of multiple individuals that ranged from 25 people (i.e., *25 Women Who Thought of it First*) to two individuals (e.g., *The Inventors Secret: What Thomas Edison told Henry Ford*). I removed these books from the selection. Moreover, some of the winners of the NCB represented scientists, engineers or people very much involved in science (e.g., *Gregor Mendel: The Friar who Grew Peas; On a Beam of light: A Story of Albert Einstein*), yet these were not in the OSTB list. These were counted as science picture book biographies. The remaining selection included 69 picture book biographies of scientists and 110 picture book biographies of non-scientists.

I acquired the picture books from the library of the University of Otago using the interlibrary loan service from other libraries in Aotearoa New Zealand and Australia. However, nine (9) of the picture book biographies of scientists were not found in these two countries. As a result, my final sample was comprised of 60 picture book biographies of scientists. Because I wanted both samples to be the same size, I randomly chose 60 picture book biographies of non-scientists. The final sample of 120 picture books will be referred to hereafter as the 'sample'. This sample is larger than similar studies on trade and picture books, which have tended to use sample sizes of fifty books or less (e.g., Boiger et al., 2013; Brunner & Abd-El-Khalick, 2017; Kelly, 2018; Sanders et al., 2018; Tsai, 2007; Vander Wege et al., 2014)

Most books were hardcover copies, and the majority came with their dust jackets. After the books arrived, these were digitized into PDF files for analysis. I then returned all the books to the respective libraries. The digitized copies of the books were dutifully kept in secure places and were only used for research purposes following fair dealing/use principles.

Appendix A shows all the picture book biographies of scientists and non-science in the sample, with their year of publication, and the name of the authors, illustrators, and main characters. I further collected some publicly available demographic information about the book's authors, illustrators (table 5.1) and main characters (table 5.2).

Table 5.1

Demographics of Authors and Illustrators[1]

Author's gender[1,2]	Science (n=60)	Non-science (n=60)	Total (n=120)
Female	43 (69.35%)	36 (58.06%)	79 (63.71%)
Male	19 (30.65%)	26 (41.94%)	45 (36.29%)
Author's ethnicity[1,2]			
White	60 (96.77%)	39 (62.90%)	99 (79.84%)
African American, or Black	2 (3.23%)	15 (24.19%)	17 (13.71%)
Latin American, Latino/a/x, or Hispanic American	0 (0.00%)	5 (8.06%)	5 (4.03%)
American Indian, or Native American	0 (0.00%)	2 (3.23%)	2 (1.61%)
East or Southeast Asian	0 (0.00%)	1 (1.61%)	1 (0.81%)
Illustrator's gender[3]			
Female	28 (50.00%)	16 (27.59%)	44 (38.60%)
Male	28 (50.00%)	42 (72.41%)	70 (61.40%)
Illustrator's ethnicity[3]			
Caucasian/White	45 (80.36%)	25 (43.10%)	70 (61.40%)
African American or Black	3 (5.36%)	25 (43.10%)	28 (24.56%)
Latin American, Latin/a/x, or Hispanic American	4 (7.14%)	6 (10.34%)	10 (8.77%)
American Indian, or Native American	0 (0.00%)	1 (1.72%)	1 (0.88%)
East or Southeast Asian	4 (7.14%)	1 (1.72%)	5 (4.39%)

[1]These are based on my own perception of their gender and ethnicity based on their names, pictures, and biographies. They do not necessarily represent how the authors and illustrators identify themselves.
[2]Some books had more than one author
[3]Some books used stock images as illustrations

5.3.3. Ethical considerations

Because content analysis usually deals with physical objects, only a few ethical issues from the use of this method of data collection and analysis are worth noting. First is the issue of honesty throughout the process. Following the work of Neuendorf (2017), Schreier (2012), and others, I committed to the ethical standards in the collection, analysis, safekeeping, and reporting of data. Moreover, I am aware of the few ethical issues that may arise with human coders. One has to do with potential negative content in the texts studied. In particular, some of the picture book biographies highlight issues of discrimination against women and ethnic groups that might be sensitive to some coders. The second coder was informed about the appearance of these issues during the training sessions and debriefed after the coding. Because the picture books are written for children between the ages of 4 and 12, the problematic issues that these included have been generally addressed with great sensitivity.

Table 5.2
Demographics of Main Character

Gender[3]	Science (n=60)	Non-science (n=60)	Total (n=120)
Female	25 (41.67%)	20 (33.33%)	45 (37.50%)
Male	35 (58.33%)	40 (66.67%)	75 (62.50%)
Ethnicity[3]			
White	51 (85.00%)	21 (35.00%)	72 (60.00%)
African American or Black	8 (13.33%)	26 (43.33%)	34 (28.33%)
Latin American, Latino/a/x, Hispanic American	0 (0.00%)	5 (8.33%)	5 (4.17%)
American Indian, or Native American	0 (0.00%)	3 (5.00%)	3 (2.50%)
East or Southeast Asian	1 (1.67%)	2 (3.33%)	3 (2.50%)
Other	0 (0.00%)	3 (5.00%)	3 (2.50%)
Current status[1]			
Historical figure	47 (78.33%)	53 (88.33%)	100 (83.33%)
Alive	13 (21.67%)	7 (11.67%)	20 (16.67%)
Country of birth[2]			
United States	32 (53.33%)	36 (60.00%)	68 (56.67%)
United Kingdom	11 (18.33%)	1 (1.67%)	12 (10.00%)
France	4 (6.67%)	2 (3.33%)	6 (5.00%)
Germany	3 (5.00%)	1 (1.67%)	4 (3.33%)
Mexico	0 (0.00%)	3 (5.00%)	3 (2.50%)
Other	10 (16.67%)	15 (25.00%)	25 (20.83%)

[1]At the time of coding (November 2020)
[2]Some characters were born in countries that currently don't exist or which changed as a result of war and colonization.
[3]These are based on my own perception of their gender and ethnicity based on their names, pictures, and biographies. They do not necessarily represent how these people identified themselves in real life.

5.4. Study 1 - Facial expressions of awe in picture book biographies

Previous studies have tried to capture the representation of emotion by using quantitative content analysis of the facial expressions in picture books (e.g., Sanders et al., 2018; Tsai, 2007; Vander Wege et al., 2014). These have catalogued the faces using systems such as the Facial Action Coding Scheme (FACS) (Ekman & Friesen, 1976) to capture the cues that the characters of the books produce and catalogue their emotions accordingly. The constructionist view sees the faces represented in systems such as the FACS (e.g., smile for happy, scowl for angry) as cultural stereotypes which correspond to what people believe an emotion should look like (Barrett et al., 2019; Robinson & Clore, 2002). In the same way that people pose these stereotypical faces when asked to make them, I argue that an illustrators' representation of an emotion in a character's facial expression will tend towards the cultural stereotype, constructed using their beliefs about what an emotion category should look like.

However, there are various complications from coding facial expressions from picture books using rigid systems such as the FACS. Previous studies have found that illustrations in picture books have a high degree of ambiguity because of the variety of techniques and styles used by illustrators that make facial expression many times difficult to outline (e.g., Vander Wege et al., 2014). As a result, it is necessary to test for the reliability of the coding by inviting a second coder.

With this in mind, the study compared the prevalence in the representation of stereotypical facial expressions of awe in picture book biographies of scientists and non-scientists. Following the aforementioned literature on the higher importance of a valued emotion category in a cultural space (Mesquita et al., 2017) my hypothesis in this study was that:

Hypothesis 1: Stereotypical representations of awe in the facial expressions of characters in picture book biographies of scientists are more frequent than those in picture book biographies of non-scientists.

5.4.1. Procedure

In this study, I followed an adapted version of the standard procedures of quantitative content analysis (e.g., Neuendorf, 2017; White & Marsh, 2006). After sampling and determining the units of coding (i.e., a human face) and analysis (i.e., the picture book), I developed a simple theory-based codebook (appendix B) with two questions and tested it on a subset of the sample. I segmented all the images in the picture book into units of context (i.e., the page). After reviewing the codebook, I coded the entire sample. Then I brought in a second coder to test for reliability. To statistically compare the differences between the two types of picture book biographies, I used simulation-based difference of means tests that account for the relatively low sample size and their non-parametric distribution. These tests were conducted in R (Core team, 2013) using the 'infer' package (Bray et al., 2018). After analysing the data, I proceeded to write up the results.

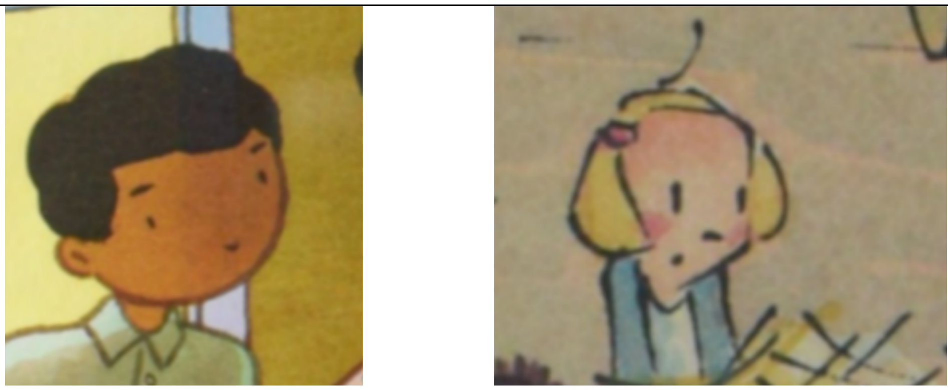
5.4.2. Materials - The coding frame

The stereotypical representation of an awe facial expression has been described as having a raised inner eyebrow, widened eyes, and an open drop-jawed mouth (Shiota et al., 2003). In this study, we evaluated every human face (unit of coding) appearing in the picture book biographies as following this description of awe. The codebook asks two simple questions: How many faces are there on this page? How many faces have a stereotypical facial expression of awe on this page? The codebook also included the description of this expression and notes on how to proceed with the coding.

5.4.3. Coding

First, I counted the total number of units of coding (i.e., human faces). The faces had to include at least eyes and mouth. When there were more than five faces in an image (e.g., depictions of a crowd) only the five most prominent faces were acknowledged. All illustrations and photographs were counted; this included the images in the covers and peritextual material (Martinez et al., 2016). In total, the 120 books had 6,234 faces (M = 51.95, SD =29.8), in 5,540 pages (M = 46.17, SD = 9.4) for an average of 1.1 faces per page. I then coded for the number of faces of awe on each page. Some books presented a challenge for coding, as many of the faces were very small or unclear as a result of the illustrator's approach and technique. For example, many artists represent their characters using a minimalistic style (Painter et al., 2013), in which faces are portrayed with very few features. As such, many faces did not include eyebrows or their mouths were only lines (for examples, see figure 5.1). Moreover, other stereotypical facial expressions also include widened eyes or open mouths (e.g., fear, surprise, singing) (see figure 5.2) compounding the high level of ambiguity in many illustration's faces resulting from stylistic differences. I allowed, therefore, a certain degree of flexibility in the coding. In circumstances where the illustrator overall drew no eyebrows, drew every eye as simple dots, or made all mouths closed, at least one of the other conditions that make a stereotypical awe face had to be satisfied. Any such ambiguous situations were discussed and resolved in conversation with the second coder.

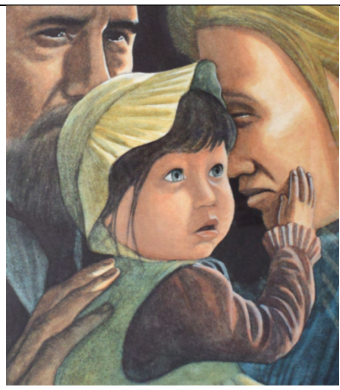
Figure 5.1
Examples of Minimalist Style Illustrations in Picture Book Sample



*The first image is taken from *Mae Among the Stars* by Roda Ahmed. The second image is from *Me, Jane* by Patrick McDonnell (see Appendix A).
**Image usage is covered under fair dealing/use principles for educational and research purposes.

Figure 5.2

Examples of Awe-like Expressions with Different Meanings in Picture Book Sample



*The first image is taken from *Handel* by M. T. Anderson. The second image is taken from *Helen's Big World* by Doreen Rappaport (see Appendix A).

**Image usage is covered under fair dealing/use principles for educational and research purposes.

5.4.4. Intercoder reliability

A second coder was introduced to the codebook and given an hour-long training session, in which the coding procedure was practised on picture books that were not part of the sample. The second coder was blind to the hypothesis. After the session, the coder received 20% of the sample (i.e., 24 books) to code. Following their coding, I met the second coder once again for a debrief session in which disagreements were resolved through consensus. After the session, the coder was thanked and received 100NZD for their work. The intercoder reliability measure for the total number of faces (Cohen's $\kappa = 0.871$) suggests an almost perfect agreement (Landis & Koch, 1977). Using this same benchmark, the reliability for stereotypical awe facial expressions per page was substantial (Cohen's $\kappa = 0.695$).

5.4.5. Results

In total, 259 faces were coded as having a stereotypical representation of awe ($M = 2.15$; $SD = 3.28$; table 5.3). For the sixty picture book biographies of scientists, the total number of awe expressions was 184 ($M = 3.07$; $SD = 3.96$). By contrast, the sixty picture book biographies of non-scientists included a total of 75 awe expressions ($M = 1.25$; $SD = 2.07$). Hypothesis testing using 5,000 permutations to create a null distribution indicated that the difference in means between both types of picture books was significant ($p < 0.001$).

Table 5.3

Descriptive Statistics of Frequency of Faces with Stereotypical Awe Expressions in Picture Book Biographies

	Mean	SD	Range	N
Science	3.07	3.96	[0, 16]	184
Non-science	1.25	2.07	[0, 8]	75

Likewise, the proportion of faces (table 5.4) with stereotypical awe expressions in picture book biographies of scientists ($M = 0.07$; $SD = 0.1$) was higher than in picture book biographies of non-scientists ($M = 0.03$; $SD = 0.04$), and this difference was also statistically significant ($p < 0.001$). Overall, the science picture book biographies in the sample contained a higher proportion of faces with stereotypical awe expressions[85].

Table 5.4
Descriptive Statistics of Proportion of Faces with Stereotypical Awe Expressions in Picture Book Biographies

	Mean	SD	Range	Median
Science	0.07	0.1	[0, 0.44]	0.05
Non-science	0.03	0.04	[0, 0.16]	0

5.4.6. Discussion

Images depicting facial expressions of awe were much more common in picture book biographies of scientists than in those featuring non-scientists. In fact, over half of the former (42 out of 60) included such stereotyped displays of this emotion, whereas significantly fewer such books included such images in the sample of the latter type (25 out of 60). Some science picture books contained multiple faces that fit the mould of the drop jaw mouth and wide-eyed expression stereotypical of this emotion. For example, the picture books of scientists such as *Barnum's Bones*, *Small Wonders*, and *The Man who Made Time Travel* contained more than a dozen such representations each (figure 5.3). Such differences between the two types of books were apparent both for the raw frequency and the overall proportion of such images. These findings suggest that visual characterizations of awe are indeed more common in science picture books than they are in similar books from other areas of society.

That said, various affordances of the picture books, such as artistic styles, presented challenges for coding. Ambiguities in the illustrations frequently made interpretations difficult (see also Vander Wege et al., 2014). For example, due to the lack of specificity of facial features (e.g., no eyebrows), many expressions did not fully correspond to the stereotypical representation of a facial expression for awe (Shiota et al., 2003). Others seemed to show mixed stereotypical emotions, approximating surprise, fear, or even joy (see

[85] Traditional non-parametric tests shows that the difference was statistically significant for raw frequency ($W = 1{,}210$; $p < 0.001$) and proportions ($W = 1143$; $p < 0.001$).

Du et al., 2014). There were also depictions of characters talking, singing, or with a wide-eyed and open-jawed expression, which made the task of identifying awe facial expressions difficult. Moreover, there were instances whereby this emotion was represented in the illustrations through other conventional signifiers of awe, such as settings (e.g., on top of a mountain), events (e.g., stargazing), and actions (e.g., freezing), that were not captured by the coding scheme. In some cases, this emotion was also represented in the text accompanying such images. To corroborate this initial study of awe-based content in children's picture books, therefore, in the next study I analysed the written text, similarly expecting to find more awe-related words in the science books than in the non-science books.

Figure 5.3

Examples of Stereotypical Facial Expression of Awe in Picture Book Biographies of Scientists

*The first image is taken from *Barnum's Bones* by Tracey E. Fern. The second image is taken from *Small Wonders* by Matthew Clark Smith. The third image is taken from *The Man who Made Time Travel* by Kathryn Lasky (see Appendix A).
**Image usage is covered under fair dealing/use principles for educational and research purposes.

5.5. Study 2 - Text data mining of representation of awe in picture book biographies

The representational content of a category, such as an emotion, is enmeshed in rich networks of associations anchored in their words and grounded in perception, action, and situations (e.g., Barsalou et al., 2008). There are various ways to approximate the content of these rich networks that represent the content of a category. On the one hand, word associations, property generation, and other production tasks shed some light on the content and structure of people's conceptual knowledge of a category (e.g., De Deyne et al., 2019). On the other hand, language models capture how words are represented within networks in-the-world by looking at vast corpora and determining the relationships between words (e.g., Landauer & Dumais, 1997). The resulting word incidences, co-occurrences, distributions, and distances from these tasks and models, point towards the stereotypical linguistic content that constitutes an important aspect of the representation of a category.

Early work using dictionaries to identify emotion content in written texts focused on explicit emotion categories (Ortony et al., 1988). Content analysis studies about emotions in the text of picture books have also focused on emotion categories (Boiger et al., 2013). More sophisticated studies of emotions in text have used TDM techniques, such as sentiment analysis, creating increasingly advanced dictionaries of measures of the valence of words (Baccianella et al., 2010) and specifically connoted emotion categories (Strapparava & Valitutti, 2004). While methods that use dictionaries have been criticized for their lack of nuance into the details of emotion situations, they are still widely used, following trends in algorithmic sophistication in TDM (see Mäntylä et al., 2018).

In this study, I use simple TDM techniques to compare the frequency of the representation of words that compose the stereotypical linguistic structure of the category 'awe' in picture book biographies of scientists versus those of non-scientists. However, measures of raw frequency do not fully capture the importance of a word in a document (Anandarajan et al., 2019). As a result, different weighting schemes have been devised to take different aspects of a document and the body of documents it comprises into account. One such weighting strategy is called 'Term Frequency Inverse Document Frequency' (TFIDF), which combines both the frequency of each word in a document and the amount of information each term carries in relation to the corpus (Aizawa, 2003).

In line with arguments about the value of the representation of this emotion in the culture of science communication (see chapter 3), I sought to test the following hypothesis:

Hypothesis 2: Representations of awe in the written text of picture book biographies of scientists are more frequent and central than those in picture book biographies of non-scientists

To compensate for some of the criticism towards dictionary-based studies, I used five different dictionaries of awe-related words derived from previous research.

5.5.1. Procedure

The main texts of the 120 picture books were manually transcribed with the help of Adobe's Acrobat Pro DC (Adobe, 2020) optical character recognition (OCR) function. After tokenizing each text, I calculated the TFIDF score for every word in every text. Following this, I calculated the frequencies of the words in the picture books for each of the five dictionaries of awe-related words and weighted these by the total number of words in each book. I also calculated a measure of the thematic weight of awe-related words in each book as the sum of TFIDF for each of the dictionaries. This measure captures the centrality (i.e., thematic weight) of a category (i.e., awe) within a document. Finally, I compared these different measures at the document level using both simulation-based difference of means test with 5,000 permutations and traditional non-parametric measures, with picture book biography type as the one factor with two levels (scientists/non-scientists). Most processing and analysis was done using the 'stats' (R Core Team, 2013), 'tidytext' (Silge & Robinson, 2016), and 'infer' (Bray et al., 2019) packages.

5.5.2. Materials

I used five different dictionaries of awe-related words to capture the frequency of representation of awe in picture books. The first is a reference dictionary of the words 'awe' and 'wonder' and their derivates (e.g., 'awe-inspiring', 'awesome', 'wonderful') taken from the Oxford English Dictionary (Simpson et al., 1989). The next three dictionaries were taken from results of previously published research that has used production tasks, such as the traditional taxonomy of relations between emotion words (Storm & Storm, 1987), the South Florida University word association norms (Nelson et al., 2004) and the recently compiled Small World of Words English norms (SWOW-EN) (De Deyne et al., 2019). I also included the results of pretrained word embeddings using the Glove algorithm (Pennington et al., 2014).

1) Expert-based dictionary

The first dictionary (appendix C) includes the word 'awe' and all its derivate forms. I included then the verb, participle, and adjective among the various derivates of the words taken from the Oxford English Dictionary (Simpson et al., 1989). Because the word 'awe' and its derivatives were not very frequent (i.e., only eight tokens), I also included the word 'wonder' and its derivatives in the dictionary (see chapter four).

2) Traditional taxonomy of emotion categories

Storm and Storm (1987) created a taxonomy of the relations of synonymy of emotion words. By contrast to other taxonomies of emotion (e.g., Johnson-Laird & Oatley, 1989), these authors did not assume the existence of a referent from which the emotion word acquires its meaning, but rather explored the lexical domain of relationships between these words through a combination of sorting and free listing activities with children, regular adults, and experts, to hierarchically classify 525 emotion-related words in the English language. The result was a series of 61 clusters that reflect certain synonymy relationships between emotion words in the English language. Words in each cluster can then be recognized by speakers of the English language, within the cultural setting of the study, as having, to a certain extent, a relationship of synonymy with each other. The resulting fourteen emotion words that clustered together with 'awe' (appendix D) gravitate around the idea of violation of expectations.

3) University of South Florida Word Association norms

The University of South Florida Word Association Norms (USF-WA) (Nelson et al., 2004) are perhaps the most cited word association norms in the literature, with over 1,000 papers. It contains the discrete free word associations (i.e., only one response per cue) for more than 5,000 English words produced by over 6,000 participants. The dictionary is composed of all the non-idiosyncratic responses to the cue word 'awe' in the USF-WA norms. Non-idiosyncratic responses are those given by more than two participants. This 20-word dictionary (appendix E) includes many of the same words as the other dictionaries. I did not include the derivate forms of these words, but rather only the word 'awe'.

4) Small World of Words norms

Similar to the South Florida University project, the Small World of Words is currently the largest word association norms in the English Language, having collected word associations of more than 12,000 English words from over 90,000 participants. By contrast to the former, it uses a continued word association task whereby the participants produced three responses to a cue (De Deyne et al., 2019). The dictionary (appendix F) includes both non-idiosyncratic out and in responses for the word awe. This means that it includes all the responses that participants made when cued with the word 'awe', and the cue words that generated the response 'awe' or 'awed'. This dictionary is larger and more diverse than all previous ones and I also included the word 'awe' in it.

5) Glove

The Global Vectors for Word Representation algorithm (Glove) (Pennington et al., 2014) is a word vectoring model invented in 2015 by a Stanford team to extract the meaning of words from context using pre-existing corpora. The model was trained on the largest of the corpora provided by the team: The Common Crawl corpus. This commonly used corpus contains 840 billion tokens for 2.2 million types. I calculated the fifty most similar words to 'awe' using Euclidean distances. I also included the word 'awe' for a total of 51 words (appendix G). This was done in Python using the '*scipy'* library (Virtanen et al., 2020).

6) The picture books' text

Because picture books are usually written for children, many include little text and simple narratives, both of which increase in complexity with the age of the target audience (Nikolajeva & Scott, 2013). Nonetheless, picture books have a more diverse vocabulary than regular speech in conversation (Montag et al., 2015). The main texts of the 120 picture book biographies included 218,334 total words (i.e., tokens) (M = 1,819.5, SD = 1,440.8) and 16,273 unique words (i.e., types). Numbers such as years, quantities, and time were included in the counts.

7) Term Frequency Inverse Document Frequency (TFIDF)

To weight each word, I used the TFIDF. Weighting schemas are used in text analytics to compensate for the differences in the total number of words and the abundance of a word in a corpus. The TFIDF is one of the most commonly combinatorial weighting schemes, as it counterbalances the frequency of a word in a document and how often it appears across all documents in a corpus (Anandarajan et al., 2019). It is the result of multiplying the number of times a term shows up in a document divided by the sum of all words (i.e., Term Frequency or TF) and the logarithm of the total number of documents divided by the number of documents that include such words (Inverse Document Frequency or IDF). It is usually given by the formula: $TFIDF = TF * IDF$. I chose this weighting scheme to compensate for the differences in the word counts of individual picture books, on the one hand, and to favour the centrality of the words in their context, on the other. Thus, words such as 'some' and 'like', which appear in several of the dictionaries and provide very little information about the value of 'awe' in the picture books, have less weight in the analysis than words such as ‘astonishment’ or ‘amazing’. The value of TFIDF scores from the words in the dictionaries is then added for each picture book to capture the ‘thematic weight’ of awe-related words in the book. This method is commonly used in text analytics to capture the relevance of a sentence in an article (see Zechner, 1996).

5.5.3. Results

Table 5.5 shows the raw word frequency using the five dictionaries in the two kinds of books. Mann-Whitney and simulated difference of means tests of weighted word frequency between science and non-science picture books (Table 5.6) revealed a significant ($p < 0.05$) difference between both types of books for dictionaries 1 and 5. The Mann-Whitney test for dictionary 2 showed a marginally significant effect ($p < 0.1$) while the simulation results suggested a significant p-value ($p = 0.03$). For dictionaries 3 and 4, however, the differences were not significant; likely the result of these dictionaries coming from word association tasks which include some very common words such as ‘some’ and ‘like’ and which do not provide much insight into the content of the emotion category ‘awe’. Effect sizes using Cliff’s δ were small for dictionaries 1 and 2, and medium for dictionary 5.

As frequencies alone do not necessarily reflect the full informational content of a word in the context of a corpus, we considered the thematic weight of the category awe (i.e., the sum of TFIDF values) to be a better indicator of the centrality of this emotion in the text. This value was again greater for science than for non-science picture books, across all of the dictionaries for the simulation test (Table 5.7). Similarly, the result of the Mann-Whitney tests were significant for four of the dictionaries. Overall, these results suggest that the thematic weight of the category awe is higher (i.e., is more central) in picture book-biographies of scientists than in those of non-scientists.

Table 5.5
Overall Raw Frequencies of Awe Related Words in Picture Book Biographies

	Dictionary 1	Dictionary 2	Dictionary 3	Dictionary 4	Dictionary 5
Science	79	35	388	738	180
Non-science	49	31	495	822	144

Table 5.6
Mann Whitney U and Difference in Means Tests of Weighted Frequencies of Awe-related Words between Picture Book Biographies

	Science - Mean (SD)	Non-science - Mean (SD)	Mann Whitney U	p-value	Cliff's δ	Difference in means p-value (simulation)
Dictionary 1	0.00104 (0.00167)	0.000381 (0.000540)	1371	**0.017****	-0.24	**0.002*****
Dictionary 2	0.0005 (0.0008)	0.0002 (0.0004)	1499	**0.073***	-0.17	**0.03****
Dictionary 3	0.00471 (0.00331)	0.00447 (0.00330)	1674	0.51	-0.07	0.685
Dictionary 4	0.00808 (0.00462)	0.00686 (0.00287)	1522	0.15	-0.15	**0.074***
Dictionary 5	0.002 (0.002)	0.001 (0.001)	1192	**0.001*****	-0.34	**0.003*****

*p<0.1, ***p* < 0.05, ****p* < 0.01.
Effect sizes based on Vargha and Delaney (2000): 0.11–< 0.28, small; 0.28–< 0.43, medium; ≥ 0.43, large

Table 5.7
Mann Whitney U and Difference in Means Tests of Sum of TFIDF Values of Awe-related Words between Picture Book Biographies

	Science - Mean (SD)	Non-science - Mean (SD)	Mann Whitney U	p-value	Cliff's δ	Difference in means p-value (simulation)
Dictionary 1	0.002(0.003)	0.0007(0.0009)	1378	**0.02****	-0.23	**<0.001*****
Dictionary 2	0.001(0.002)	0.0004(0.0008)	1480	**0.057***	-0.18	**0.009*****
Dictionary 3	0.004(0.003)	0.003(0.003)	1406	0.39	-0.22	**0.041****
Dictionary 4	0.01(0.008)	0.007(0.004)	1499	**0.066***	-0.20	**0.014****
Dictionary 5	0.005(0.004)	0.003(0.003)	1224	**0.002*****	-0.32	**0.008*****

*p<0.1, ***p* < 0.05, ****p* < 0.01.
Effect sizes based on Vargha and Delaney (2000): 0.11–< 0.28, small; 0.28–< 0.43, medium; ≥ 0.43, large

5.5.4. Discussion

The findings from this study suggest that awe-related words are more frequent, and more central, to picture book biographies of scientists than those of non-scientists. For three of the five dictionaries, weighted frequencies comparisons revealed that awe-related words were overrepresented in the scientist book type. The two dictionaries for which this was not the case were derived from word-association norms and included common auxiliary terms such as a 'some' and 'like', which have little to do with the stereotypical conceptualization of awe. Moreover, the sum of TFIDF values on picture book biographies of scientists was for the most part, higher than in those of non-scientists, indicating that, in books about science, awe had a greater centrality in these books.

Given that it is derived from applying the Glove algorithm to the Common Crawl corpus (Pennington et al., 2014), the last dictionary is perhaps the most robust of the five, capturing the words most commonly associated with awe in the same medium as the picture books: writing. The significance level and effect sizes observed for this dictionary throughout the two tests lends credence to the overall findings on the incidence of this emotion's representation in science picture books.

In general, the results from Study 2 applied to the range of dictionaries used, which are the products of expert consultation, production tasks, and corpus-based methods. As with the previous study focusing on facial expressions of awe, the pattern of text data for the present study suggests that this emotion is especially valued in life stories centring on science. The larger implications of these findings will be explored in the general discussion section.

5.6. Study 3 - Representation of awe situations in picture book biographies of children

Representations of awe are important to a variety of domains outside science communication, such as tourism (Coghlan et al., 2012), religion (e.g., Krause & Hayward, 2015), and the world of art (e.g., Konečni, 2008). Social representations in these domains assume the forms and functions in relation to the different mandates of these cultural spaces (e.g., Mesquita et al., 2017). The situations where awe is represented in science communication and the roles this emotion assumes in these social representations will reflect this culture's beliefs, values, norms, goals, and worldviews.

Previous work on the content of social representations of emotion in picture books has focused on elements of an emotion situation, such as valence, arousal, and the social situations of the agents displaying the emotion (Sanders et al., 2018; Tsai et al., 2007; Vander Wege et al., 2014). Function has also been investigated by these researchers, although for the most part they have assumed a one-to-one correspondence between an emotion category (e.g., anger) and its alleged function (e.g., disengaging) (Sanders et al., 2018; Vander Wege et al., 2014). Moreover, these studies have looked at characteristics of the character experiencing the emotion such as gender (e.g., Sanders et al., 2018). Such work has observed differences in the way emotions are represented in picture books across different cultures, comparing, for example, Taiwan and the US (Tsai, 2007), Belgium and the US (Boiger et al., 2013) and Hispanic and European American picture books in the US (Sanders et al., 2018).

I used QCA to expand on the foregoing work and to look at the different elements of awe situations represented in picture books, as well as the characteristics of the characters who are portrayed as experiencing this emotion. I then compared how awe is represented in books from within the culture of science communication, and from outside this cultural space.

To address these issues, I used the results from the first study to identify the illustrations in which awe is represented (i.e., those including a stereotypical awe face). I then coded for the elements co-occurring with these depictions of awe, to answer the following questions:

Question 1: What are the elements of an awe situation represented in picture book biographies of scientists and non-scientists?

Question 2: Who is represented as experiencing awe in picture book biographies of scientists and non-scientists?

Question 3: How are the representations of awe in picture book biographies of scientists different from the representations of awe in other picture book biographies?

This was, therefore, a descriptive study that aimed to document the representation of this emotion. Following the constructionist framework, I expected to find considerable variation in how awe is represented in the picture books of scientists. I also envisaged possible differences in the elements of the emotion, as well as the people shown as experiencing awe, between the biographies of scientists and those of non-scientists.

5.6.1. Procedure

I used an adapted version of QCA (Schreier, 2012) on the picture books split into two stages. The first stage takes as the unit of coding and analysis the visual unit, which is comprised of the illustration that includes a stereotypical awe facial expression and its accompanying text. Because in some illustrations there was more than one character represented as experiencing this emotion, I utilized a second stage, in which the unit of coding and analysis was the individual represented as having the emotion rather than the whole illustration. The steps in the procedure were as follows:

1) *First segmentation*. Following a thematic criterion (Schreier, 2012), I segmented all the picture books into the illustrations that represented awe situations. The thematic criterion was all the illustrations that contained a stereotypical facial expression (study

1). The illustration and its accompanying text were therefore the unit of coding and will be referred to as the visual unit.

2) *Construction of preliminary main categories*. Following the analytical framework in chapter three, I created 12 top-down main categories.
3) *Pilot*. I tested the preliminary main categories on 10% of the visual units. I identified various categories that did not appear or could not be inferred in most picture books, reducing the number of main categories to five situational elements.
4) *Abstraction and synthesis*. I coded another 10% of visual units. The coded units were abstracted and synthesized to generic subcategories based on both top-down typologies from previous research and bottom-up induction.
5) *Main coding*. I coded all references into the subcategories.
6) *Reliability assessment*. I brought in a second coder to assess the coding frame. The second coder was trained in an hour-long session. This person coded 20% of the visual units with the main categories. I then performed a reliability test based on the frame using Cohen's kappa.
7) *Second segmentation*. Next, I segmented the visual units following the thematic criterion of the individuals represented as experiencing this emotion.
8) *Construction of preliminary categories*. Following the dimensions about the individual used in previous research (e.g., Vander Wege et al., 2014), and adding further demographic dimensions, I created a new coding frame that included four categories about the person represented as experiencing the emotion. I also included a category for the action being performed by the individual as an important element of a situation from the analytical framework.
9) *Pilot*. I pilot-tested the code on 10% of the sample, which allowed me to refine the categories. I identified that actions had to be disaggregated into three different dimensions to capture different aspects of movement. I created the subcategories for each of these dimensions based on previous research.
10) *Coding for main categories*. I coded the whole sample using the refined coding frame. Because the seven categories had all been clearly defined, there was no need for abstraction and synthesis.
11) *Reliability assessment.* A second coder was again brought to code for 17% of the sample. I performed a reliability test using Cohen's kappa and disagreements were discussed in a debriefing session.

12) *Reporting the results*. I created frequency tables and matrixes to present the data and wrote the results.

The segmentation, coding, and analysis were done using NVivo 12 for Mac (QSR International, 1999).

5.6.2. Segmentation

I went through the results of the first study to segment the picture book biographies into the visual units that include stereotypical representations of facial expressions of awe. I only accounted for representations of facial expressions of awe from the main text of the books, as representations in other sections, such as the peritext or the covers, were sometimes repetitions from those in the main text and these did not include textual references to the action being represented. The sample of representations of awe amounted to 154 visual units (109 science, 45 non-science).

Following this, I segmented the visual units into all the individuals represented as having this emotion in each visual unit. For cases in which there were more than five representations, I only accounted five of these to avoid skewing the sample[86]. In total, there were 242 individuals represented as experiencing awe (170 science, 72 non-science).

5.6.3. Materials - The coding frame

The two coding frames include five categories representing aspects of the situation and seven categories about the actions and characteristics of the individual depicted as experiencing awe.

1) *Attention foci: Agent, object, or action, that is the focus of attention*. The five subcategories were taken from categories highlighted in previous awe research (e.g., Keltner & Haidt, 2003; Shiota et al., 2007; Yaden et al., 2019).
    a. Accomplishment
    b. Human-made artefact
    c. Natural object
    d. Non-human living organism

[86] This only happened in three illustrations in which the demographics and actions represented were very similar.

e. Person

2) *Social context*: Number of people present in the awe situation. I adapted Keltner's and Haidt (1999) four levels of analysis of social situations to determine the four subcategories.
   a. Alone
   b. Dyad
   c. Small group
   d. Crowd
3) *Setting*: The physical place where the awe situation occurs. Studies of picture books have used typologies of the environment to describe the setting where an action takes place (Babb et al., 2018; Williams Jr. et al., 2012). I adapted these by dividing the setting into five groupings.
   a. Natural (wilderness area, no human presence)
   b. Modified (natural area that has been transformed such as rural farmland or gardens)
   c. Built outdoors (outside settings that have been completely built such as cities and suburbs)
   d. Built indoors (indoor settings that have been completely built such as rooms and halls)
   e. Unclear (non-descript settings)
4) *Event*: Background event in which the awe situation occurs. I adapted the typology of events devised by Getz (2008) to include six subcategories.
   a. Arts, culture, and entertainment
   b. Business and trade
   c. Private events
   d. Public and political
   e. Scientific and educational
   f. Sports and recreation
5) *Outcomes*: Results of the awe situation. There is no typology in the literature on the different functions awe can accomplish. The literature, however, mentions a few outcomes of this emotion such as curiosity and learning (e.g., Valdesolo et al., 2017). I constructed the six subcategories for this element using some of these previous descriptions and inductively.

a. Admiration
b. Entertainment
c. Learning
d. Motivation
e. Inspiration
f. Shock

6) *Action* - *Direction of gaze*. What is the direction of the gaze of the individual experiencing awe? Semiotic work on picture books (e.g., Painter et al., 2013) suggests the importance of the direction of gaze at identifying the relationship between an individual and the rest of the scene being represented.
    a. Looking up
    b. Looking straight
    c. Looking down
7) *Action - Relationship to the object of focus*. What is the direction of the movement of the individual in relation to the object/person of focus?
    a. Engaging with the object/person
    b. Not moving
    c. Moving away from object/person
8) *Action - Communication*. What communicative action is the individual performing?
    a. Clapping
    b. Communicating verbally
    c. Covering mouth
    d. Pointing
    e. Writing
9) *Age.* In what age group is the individual? Baby/Child/Adult
10) *Gender*. What is the apparent gender of the individual experiencing awe? Male/Female/Other
11) *Ethnicity*. What is the apparent ethnicity of the individual experience awe?
    a. African American or Black
    b. American Indian, or Native American
    c. East or Southeast Asian
    d. Hispanic/Latinx
    e. Middle Eastern/Arab

f. White
g. Other

12) *Protagonist*. Is the individual experiencing awe the main character of the picture book? Yes/No

5.6.4. Intercoder reliability

A second coder was brought in to test the reliability of the coding frame. They partook in a one-hour training session after which they received two codebooks (appendix H and I) and spreadsheets for the visual units and the individuals. They also received scanned versions of thirty (n = 30) visual units where awe is occurring (20% of the visual unit sample) and forty (n = 40) images of individuals with the stereotypical facial expression of awe (17% of the sample of individuals expressing awe), which they were asked to code alone and were blind to the purpose of the coding. We later met for a debriefing session after which they were thanked and paid 100NZD for their work. Disagreements were discussed and resolved during this debriefing session.

Table 5.8
Intercoder Reliability for Visual Units

Item	Cohen's κ (n = 30)
Attention foci	0.79
Social context	0.91
Setting	0.72
Event	0.73
Outcome	0.62

Table 5.9
Intercoder Reliability for Individuals

Item	Cohen's κ (n = 40)
Action	
Looking direction	0.77
Direction of movement	0.71
Communicative expression	0.72
Individual's characteristics	
Age	0.91
Gender	0.69
Ethnicity	1
Main protagonist	0.9

Results from the intercoder reliability assessment are presented in tables 5.8 and 5.9. These indicate an overall high degree of reliability for all items. Some of these showed perfect or almost perfect agreement between both coders such as ethnicity, age, and social context. Some others showed less of an agreement such as outcome and gender, though these were all within acceptable ranges (Landis & Koch, 1977).

5.6.5. Results

1) Attention foci

Table 5.10 shows that, overall, there was a diversity of objects, agents, and actions represented as being the centre of attention in the illustrations. From bubbles and the Ferris Wheel, to the tricks from a horse and seeing a dancing performance, awe is represented in picture books as being caused by myriad objects, agents, and actions, with ostensibly little in common. Moreover, there were differences between the attention foci for this emotion in science and non-science picture books. Living organisms and natural objects are commonly represented as the main source of this emotional reaction in science picture books, whereas accomplishments and people constitute most of the awe elicitors in picture books outside of this cultural space.

Table 5.10
Frequency of Representations of Attention Foci

Agent, object, action	Science (n=109)	Non-Science (n =45)	Total (n =154)
Accomplishments	7 (6.42%)	5 (11.11%)	12 (7.79%)
Human-made artefact	42 (38.53%)	14 (31.11%)	56 (36.36%)
Living organisms	27 (24.77%)	4 (8.89%)	31 (20.13%)
Natural object	23 (21.1%)	2 (4.44%)	25 (16.23%)
Person	10 (9.17%)	20 (44.44%)	30 (19.48%)

2) Social circumstance

As table 5.11 reveals, the representation of awe occurs in all sorts of social situations. Overall, non-science picture books represent awe situations as being most frequent in a crowd, while science picture books tend to depict situations in which the individual is alone more often.

Table 5.11
Frequency of Representation of Social Circumstance

Social circumstance	Science (n=109)	Non-Science (n=45)	Total (n=154)
Alone	39 (35.78%)	5 (11.11%)	44 (28.57%)
Dyad	26 (23.85%)	6 (13.33%)	32 (20.78%)
Small group	23 (21.1%)	8 (17.78%)	31 (20.13%)
A crowd	21(19.27%)	26 (57.78%)	47 (30.52%)

3) Setting

Globally, representations of awe in picture book biographies occur in a variety of environments but mostly in built indoor environments (table 5.12). However, there were slight differences between the two groups, with awe being represented in natural and modified environments more frequently in science picture books than in their non-science counterparts. These included gardens, parks, forests, deserts, and other outdoor spaces.

Table 5.12

Frequency of Representations of Setting

Setting	Science (n=109)	Non-Science (n=45)	Total (n=154)
Built indoors	51 (46.79%)	27 (60%)	78 (50.65%)
Built outdoors	19 (17.43%)	8 (17.78%)	27 (17.53%)
Modified	16 (14.68%)	3 (6.67%)	19 (12.34%)
Natural	16 (14.68%)	3 (6.67%)	29 (12.34%)
Unclear	7 (6.42%)	4 (8.89%)	11 (7.14%)

4) Events

Table 5.13 indicates that awe occurs in a wide range of events, including pottery making, presidential visits, watching television, or just having dinner. It is not surprising that the majority of awe represented in picture book biographies of scientists occurs during scientific and educational events. This included exploring nature, working at a lab, and attending a rocket launch. By contrast, a good proportion of representations in non-science picture book biographies occurred in events related to the entertainment industry. This included concerts, dance shows, and visits to art museums.

Table 5.13

Frequency of Representations of Event

Event	Science (n=109)	Non-Science (n=45)	Total (n=154)
Arts, culture, and entertainment	8 (7.34%)	21 (45.67%)	29 (18.83%)
Business and trade	2 (1.83%)	3 (6.67%)	5 (3.25%)
Private	19 (17.43%)	7 (15.56%)	26 (16.88%)
Public and Political	5 (4.59%)	9 (20%)	14 (9.09%)
Scientific and Educational	64 (58.72%)	3 (6.67%)	67 (43.51%)
Sports and Recreation	11 (10.09%)	2 (4.44%)	13 (8.44%)

5) Outcomes

As table 5.14 suggests, there are a wide-ranging set of outcomes that accompany an awe situation, represented in both picture book biographies of scientists and non-scientists. Overall, however, the most common outcome of this emotion was to admire the attention foci. Whether a person (e.g., a dancer, a scientist), an object (e.g., a light bulb, a painting), or the natural world (e.g., the ocean, birds) the most frequent social function represented across all picture books was that of assigning value to that source of attention through its recognition and praise. Nonetheless, a few differences appeared between both samples. For example, picture book biographies of scientists sometimes represented experiences of awe as inspiring an individual to become a person of science. This function was mostly not present in representations of awe in non-science biographies. Picture book biographies of scientists also showed individuals as learning something from awe experiences more often than in non-science picture books. By contrast, situations where awe was represented in picture book biographies of non-scientists showed people experiencing such emotion commonly being entertained through it. Nonetheless, both types of picture books show a wide range of functions for this emotion.

Table 5.14
Frequency of Representations of Outcome

Outcome	Science (n=109)	Non-Science (n=45)	Total (n=154)
Admiration	45 (41.28%)	22 (48.89%)	67 (43.51%)
Entertainment	0 (0%)	11 (24.44%)	11 (7.14%)
Inspiration	18 (16.51%)	1 (2.22%)	19 (12.34%)
Learning	20 (18.35%)	3 (6.67%)	23 (14.94%)
Motivation	22 (20.18%)	5 (11.11%)	27 (17.53%)
Shock	4 (3.67%)	3 (6.67%)	7 (4.55%)

6) Actions

As table 5.15 shows, individuals illustrated as experiencing awe were represented doing a variety of actions. First, they were illustrated as looking in different directions. A greater proportion of individuals are both looking up or down rather than across in picture book biographies of scientists. This contrasts with most of the individuals looking across in non-science picture books. Second, the movement directed towards the object or agent of focus in the representation shows the majority of individuals as standing still. However, in some picture book biographies of scientists, the individual is shown as approaching and engaging with the object or person by contrast to biographies of non-scientists in which this behaviour is represented less often. Lastly, besides the stereotypical facial expression (i.e., jaw-dropped mouth or raised eyebrows), there was not much additional communication (e.g., gestures, actions, or verbal communication), represented in awe situations. The lack of other communicative actions, however, might be due to the medium and the thematic criterion used to determine which illustrations to analyse. Nonetheless, there were a variety of other communicative signs, such as clapping, pointing, or covering the mouth represented, suggesting that awe is communicated bodily, and thus represented in ways beyond just the stereotypical facial display.

Table 5.15
Action of the Individual Experiencing Awe

Looking direction	Science (n=170)	Non-Science (n=72)	Total (n=242)
Across	48 (28.24%)	38 (52.78%)	86 (35.54%)
Down	52 (30.59%)	8 (11.11%)	60 (24.79%)
Up	70 (41.18%)	26 (36.11%)	96 (39.67%)
Direction of movement			
Moving towards the object	40 (23.53%)	7 (9.72%)	47 (19.42%)
Not moving	125 (73.53%)	63 (87.5%)	188 (77.69%)
Moving away	5 (2.94%)	2 (2.78%)	7 (2.89%)
Communicative expression			
Clapping	1 (0.59%)	2 (2.78%)	3 (1.24%)
Communicating it verbally	5 (2.94%)	1 (1.39%)	6 (2.48%)
Covering mouth	7 (4.12%)	1 (1.39%)	98(3.31%)
None	144 (84.71%)	61 (84.72%)	205 (84.71%)
Pointing	10 (5.88%)	7 (9.72%)	17 (7.02%)
Writing	3 (1.76%)	0 (0.00%)	3 (1.24%)

7) Characteristics of the individual experiencing awe

Table 5.16 shows the variety of characteristics of the individual represented as experiencing awe. Age-wise, most picture books showed adults experiencing this emotion. There were, however, quite a few representations of children having this emotion, particularly in the science picture books. When it comes to gender, however, there was a considerable difference between female and male representations in the frequency of awe in picture book biographies; 71% of the characters represented as having this emotion were men. This is despite the fact that 40% of the biographies of scientists were of women. Moreover, almost four out of five illustrations of people with the facial expressions of awe were of white people. Finally, it is worth noting that in picture book biographies of scientists, two of five illustrations were of the main protagonists experiencing this emotion. A larger proportion of the representations of this expression in picture book biographies of non-scientists were made by people other than the protagonist.

Table 5.16
Characteristics of the Individual Experiencing Awe

Age	Science (n=170)	Non-Science (n=72)	Total (n=242)
Adult	108 (68.06%)	49 (68.06%)	157 (64.88%)
Baby	5 (2.94%)	2 (2.78%)	7 (2.89%)
Child	57 (33.53%)	21 (29.17%)	78 (32.23%)
Gender			
Female	43 (25.29%)	28 (38.89%)	71 (29.34%)
Male	127 (74.71%)	44 (61.11%)	171(70.66%)
Ethnicity			
Arab or Middle Eastern	0 (0.00%)	1 (1.39%)	1 (0.41%)
East or Southeast Asian	0 (0.00%)	0 (0.00%)	0 (0.00%)
African American or Black	22 (12.94%)	15 (20.83%)	37 (15.29%)
Hispanic or Latin/a/o/x	0 (0.00%)	3 (4.17%)	3 (1.24%)
Native American	0 (0.00%)	7 (9.72%)	7 (2.89%)
White	148 (87.06%)	46 (63.89%)	194 (80.17%)
Main protagonist			
No	106 (62.35%)	60 (83.33%)	166 (68.6%)
Yes	64 (37.65%)	12 (16.67%)	76 (31.4%)

5.6.6. Discussion

The results showed a large variety of elements accompanying the situations whereby a stereotypical awe facial expression is illustrated, in both picture book biographies of scientists and non-scientists. Consistent with the constructionist view on emotion, there was no one consistent element of form that accompanied all the representations of this emotion, despite the selection criterion for analysis being based on a stereotype (i.e., a facial expression). The elicitors, settings, events, social circumstances, actions, or any other element of a situation that accompanies awe, varied greatly across instances of the emotion. The results highlight the variety of ways in which this emotion is represented.

The same can be said for the function of the awe situation represented. Again, the constructionist view argues that there is no one-to-one correspondence between an emotion category and a specific function. The results here suggest that this emotion serves a variety of functions, including those which have been mentioned in the previous literature, such as making people curious (Anderson et al., 2020), a personal realization (Schneider, 2017), or learning (Valdesolo et al., 2017). As all other emotions, awe is represented to serve the needs of a particular situation; considering the diversity of situations in which it occurs, it is only to be expected that it will produce a variety of outcomes as a function of those situations.

More importantly for the purpose of this research, there were several differences in the representation of form, function, and characteristics of the individual experiencing awe between science and non-science picture books. For example, biographies of scientists illustrated a large proportion of individuals experiencing awe as a result of encounters with natural organisms (e.g., mushrooms, birds) and objects (e.g., the moon, mountains). The same can be said about the type of setting, events, and social context, whereby science picture books showed a predilection of representing awe in natural environments and research-related contexts in which the individual was alone. The stereotype of the solitary scientist doing research alone outdoors and being in awe with nature matches long-held romantic notions of scientific exploration and adventure embodied in the life of Humboldt, Darwin, and other such explorers (see Holmes, 2008; Wulf, 2015).

There were also some differences in how movement was represented, whereby biographies of scientists showed individuals looking both up and down, rather than across, more frequently. Semiotic studies of picture books suggest that the directionality of eyesight indicates the power relationship between the individual and the object or person they are looking towards (Painter et al., 2013). Individuals in picture book biographies of scientists are often shown either looking up, whether it is at the sky (e.g., Carl Sagan) or at the scientists (e.g., Nikola Tesla), or staring down, at an experiment (e.g., Marie Curie) or at nature (e.g., Jean Henri Fabre) (figure 5.4). This implies both a position of submission towards the genius of an individual or smallness towards the cosmos, or a relation of dominance over nature. By contrast, the line of sight for most images of awe in picture book biographies of non-scientists is across, connoting an equal status relation between the awed and the object of awe (figure 5.5). Moreover, some picture book biographies of scientists show a movement towards the object or person that caused the awe situation, suggesting a function of active engagement, whether through control, investigation, or use. By contrast, most agents assume a passive role in the depictions of awe in the biographies of non-scientists, suggesting a different kind of stereotypical function for this emotion in spaces outside of science communication. The differences in outcomes, in which curiosity and learning were more frequent in science picture books, suggest that this interpretation of the different functionalities for this emotion category inside and outside the culture of science communication is valid.

Figure 5.4

Examples of Illustrations of Characters Looking Up and Down when Experiencing Awe

*The first image is taken from *Star Stuff* by Stephanie Roth Sisson. The second image is taken from *Electric Wizard* by Elizabeth Rusch. The third image is taken from *Marie Curie* by Demi. The fourth image is from *Small Wonders* by Matthew Clark Smith (see Appendix A).

**Image usage is covered under fair dealing/use principles for educational and research purposes.

Figure 5.5

Examples of Illustrations of Characters Looking Across when Experiencing Awe

*The first image is taken from *Emmanuel's dream* by Laurie Ann Thompson and Sean Qualls. The second image is taken from *Hiawatha and the Peacemaker* by Robbie Robertson. The third image is taken from *Josephine* by Patricia Hruby Powell (see Appendix A).

**Image usage is covered under fair dealing/use principles for educational and research purposes.

Picture book biographies of scientists also often showed the protagonist to be the person experiencing awe. The importance of the scientists, and not a bystander, as being the person who experiences awe suggests the centrality of this emotion within the representational aesthetics of this cultural space. Importantly, a frequent trope was that of the main character having an encounter with awe as a child, an event that inspired the individual to pursue their career as a scientist. Whether it was an early encounter with nature that drove them to become a biologist (e.g., Rachel Carson), an experience with computers that made them become an analyst (e.g., Margaret Hamilton), or a sudden awareness of the night sky inspiring them to become an astronomer (e.g., Carl Sagan, Neil de Grasse Tyson), this stereotype of an inspiring discrete awe-related incident from childhood suggests the centrality of this emotion in the organization of people's affective relationships to science. This is in line with one of the main goals of science communication: persuading future generations on the "value of careers in science" (Trench & Junker, 2001, p. 3). Providing a narrative arc in which a strong emotive situation leads to a professional choice in STEM activities falls squarely within the mandates held by some members of this cultural space.

Finally, it is worth highlighting how the gender and race of the person experiencing awe are unevenly represented in the depiction of this emotion. The great majority of illustrations of people experiencing awe were of white men. While there were exceptions that showed both non-white characters (e.g., Neil de Grasse Tyson), and women (e.g., Rachel Carson) as experiencing awe, for the most part, the images of people in these books conformed to this exclusionary stereotype. This is despite a good proportion of picture books being about women (37%) and non-white people (40%). This finding suggests the continuation of discourses of awe based on the sublime aesthetic, which reflect a powerful gender and Eurocentric bias (Freeman, 1995; A. K. Mellor, 1993; Yaeger, 1989). While the gendered and racialized coding of this emotion has been noted by scholars of the sublime, no study prior to the present work into the representation of awe has documented this stereotype empirically. This is particularly important for science communication, a field in which creating participatory spaces where people from any background can affectively relate with science is a necessary condition for engaging with communities "feeling left out" (Humm et al., 2020, p. 164) from this cultural space.

Research into the content of the representations of awe in picture book biographies both of scientists and non-scientists show a large variety of forms, functions, and individuals experiencing this emotion. The results from the present study suggest that, for the culture of science communication, there are different varieties of awe. Furthermore, these varieties are distinct from those apparent in other cultural spaces. These findings are both in line with the constructionist view of emotion and the overall argument of this thesis.

5.7. General discussion

I have argued that awe is a valued emotion in the culture of science communication. Hence, I hypothesized that this emotion should be represented at a higher frequency and centrality through the artefacts produced in this cultural space. In studying the facial expressions and written texts in picture book biographies of scientists, comparing such content to that of picture book biographies of non-scientists, these general predictions were supported.

Moreover, I observed a variety of forms and functions tagged to the representation of this emotion in these artefacts. The forms and functions of an emotion in a culture are products of the cultural mandates that suffuse this space (Mesquita et al., 2017). The many forms and functions observed in the present analysis suggest the variety of norms, values, beliefs, and other mandates within this culture. More importantly, there were noticeable contrasts between the representation of this emotion within and outside of science communication. This suggests that, despite the varieties of awe in science communication, there are some normative set of beliefs, values, identities, and goals that constitute the representational repertoire for this emotion in this cultural space.

Finally, noting the prevalence of this emotion in children's picture books establishes a mechanism through which children begin to acquire the conceptual knowledge to construct this emotion. While commonly used emotions (e.g., happiness, sadness, disgust) are learned by an infant from their caregivers, emotion categories such as awe, marvel, and astonishment rarely appear in natural language during interactions between parents and children ages zero to seven[87]. Picture books, by contrast, include a much larger variety of words than regular child-directed speech, hence parents and educators who read these are supporting the learning of categories that have low frequency use in the English language (Montag et al., 2015). Other cultural spaces where awe is valued such as churches (e.g., Krause & Hayward, 2014) or tourism experiences (Coghlan et al., 2012) may also be spaces where children encounter awe-related language and expressions early. However, considering the importance of picture books in the cognitive development of children (Kümmerling-Meibauer & Meibauer, 2013, 2015), and how these books socialize children into the emotions of a particular cultural space (Garner & Parker, 2018; Tsai et al., 2007), the results of this study suggest that picture books are a starting point for the development of the emotional knowledge of awe, one through which they can later construct their own emotional experiences of this emotion. If this is the case, the higher frequency and centrality of this emotion in picture books from the culture of science communication would mean that children socialized into this space would be getting a head start in their affective learning of awe.

5.8. Limitations

Nevertheless, several limitations of the present work are worth noting. In general, results from convenience samples are difficult to generalize to the entirety of the population.

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[87] This is true especially of vocabulary that is not used in daily conversation. Awe is not a word that parents commonly use when talking to their children. A quick search on ChildFreq (Bååth, 2010) - a tool that searches 5,000 transcriptions of conversations with children ages six months to seven years from the CHILDES database (MacWhinney, 2000) that includes 3,500,000 words - shows no entries for 'awe'. By contrast words such as happy (n= 1084), sad (n=332), scared (n = 405) and other emotion categories are produced relatively frequent.

Although this study used a good sample size and included some highly consumed picture book biographies, as suggested by the fact that they were all award-winning books, it is problematic to conclude that the findings could be applied to all science picture books, or even that they apply to picture book biographies. It is worth remembering that picture book biographies of scientists are different in many ways from the informational books that are very popular as science books for children. Moreover, while the sample was chosen from award-winning biographies from the United States and these books are sold around the world through the strength and size of this country's publishing industry, any generalization to other English-speaking contexts such as those in Aotearoa New Zealand is cautioned. Finally, creating better dictionaries of words that constitute the representational content of an emotion, and devising nuanced typologies with which to code the elements of a situation, could potentially help in better establishing the frequency, centrality, form, and function of emotions in this kind of studies. The newness of this kind of research makes this study only a first step towards exploring the incidence and diversity of emotion representations in cultural artefacts.

5.9. Conclusion and future directions

As far as I am aware, this exploratory study is the first of its kind to show differences in the social representation of one emotion (i.e., awe) in one type of artefact (i.e., children's picture book biographies) of the culture of science communication. Future studies might examine other cultural artefacts (e.g., science documentaries, comic books) to explore how awe and other emotions (e.g., sadness, anger, joy) are represented within this cultural space, in English and other languages. Such investigations can also look for differences in how awe, and other emotions, are represented across cultural artefacts from different disciplines (e.g., biology vs., astronomy), countries (e.g., Aotearoa New Zealand vs. the United Kingdom) and time periods (e.g., 20th vs 21st centuries), among the many subcultural comparisons that can be done, as ways into picking the diversity and change of the representation of this emotion through space and time. At the same time, such work can compare these representations to those in other types of artefacts derived from different cultural spaces where this emotion is common (e.g., religious communities, art, tourism). Lastly, establishing the way in which science picture books are consumed (e.g., who consumes them; where are these read; how do children, parents, and educators relate to these), and how these relate to the consumption of other cultural artefacts from the culture of science communication, can help guide our understanding of how people are socialized into this cultural space, as well as the role of affective categories such as awe in this socialization.

Chapter six - Assessing the mental representation of awe in science communication through the word association paradigm

6. Introduction

Different degrees of conceptual skill manifest as a variety of features. First, people with increasing levels of skill show different degrees of information-processing abilities, which allow them to perform a task with growing expertise (e.g., Biederman & Shiffrar, 1987; Holt & Beilock, 2006). Similarly, people with a higher degree of conceptual skill show different forms of knowledge about the subject area in which they have said skills. Experts show specialized knowledge in particular domains that manifests in the diversity, sophistication, and specificity of the content of knowledge in those domains (e.g., K. E. Johnson & Mervis, 1997; Tanaka & Taylor, 1991). Finally, people with growing degrees of skill show increasing levels of structural differentiation and organization in their conceptual knowledge (e.g., Crowe & Prescott, 2003). These features distinguish the conceptual skills of people with rising levels of experience with any category, including the mental representation of emotions (Hoemann Nielson et al., 2020).

As I showed in the previous chapter, awe appears to be represented with a higher frequency and centrality in the products of this cultural space, and people who navigate it (e.g., going to science museums, reading science magazines, attending science festivals) find themselves in more situations that involve this emotion category. Being valued in this cultural space, people are more likely to interact with the category 'awe' and have experiences of (i.e., practice) this emotion. Hence, repeated experience with awe should make them more skilled in the conceptualizations of this category; expertise which should manifest in divergent processing abilities, differentiated content, and a specialized structure of knowledge.

The five studies presented in this chapter assess the differences in conceptual skills between those who engage with science communication and those who don't. As skill differences manifest in a variety of phenomena, three questions guide this chapter: Are there differences in the processing abilities of the emotion category 'awe' in those who participate in the culture of science communication? Are there differences in the content of these representations of awe between those who participate in this culture and those who do not? Are there differences in the structure of knowledge for this emotion among those engaged and those disengaged with this cultural space? Studies 1 and 2 evaluate people's processing of 'awe' comparing the activation of different representational systems during a word association task. Study 3 evaluates the content of the responses in the domain of science communication by comparing their production of natural kind responses. In study 4, I segment the sample to compare the perceptual strength in different modalities and concreteness of the word association norms produced by the *engaged*, *interested*, and *disengaged* from science communication. Finally, study 5 analyses the structure of these responses using cluster analysis.

Following the language and situated simulation theory of the representation of concepts (LASS; Barsalou et al., 2008), the constructionist view of emotions (Barrett, 2017a) and its take on expertise (Hoemann Nielson et al., 2020) (see chapter three), I argue that participants' conceptualization of awe, communicated in the responses to a word association task, should differ for the different levels of engagement with the culture of science communication. The differences in processing abilities should manifest in a differentiated activation of the linguistic and simulations systems during the task. Moreover, I also argue that the content of the representations from people who engage with the culture of science communication and those who don't will also differ, as the content of those who do engage should reflect some of this culture's mandates (Mesquita et al., 2017). Finally, I expect to see differences in the structure of the responses to the cue 'awe' among the engaged and the disengaged. The responses of participants with a higher level of experience with this emotion should then show a higher degree of order and thematic coherence.

I begin this chapter by presenting a brief overview of the word association production paradigm. Then I provide a short literature review of studies using production paradigms to test differences in the mental representation of a category. Following this, I describe the set-up of each of the five studies including their methods and results. I conclude with a general discussion of the results of the studies, noting their limitations, and considering future directions for this research.

6.1. Methodological overview

The basic setup of the word association task[88] consists of giving a single word cue to a person and then asking them to produce one or a set of associates as they come to mind. The main assumption of this task is that the associations produced give a somewhat unfiltered approximation to people's representational processes, such as conceptualization, linguistic association, the interaction between lexical and conceptual knowledge, conceptual combination, and so on (e.g., De Deyne et al., 2019; De Deyne & Storms, 2008a, 2008b; de Groot, 1989; Deese, 1965; Nelson et al., 2004; Santos et al., 2011). The paradigm belongs to a family of production tasks that includes *feature listing*[89] (e.g., Barsalou & Wiemer-Hastings, 2005; McRae et al., 2005; Rosch & Mervis, 1975), whereby people are asked to produce as many features as possible of an object, and *category fluency* tasks[90] (e.g., Crowe & Prescott, 2003; Storm & Storm, 1987), whereby people are asked to name all the objects about a category under a certain time frame.

It is worth highlighting that word association norms, as with all data collection strategies, provide only a partial view of the content and structure of knowledge (e.g., Barsalou & Wiemer-Hastings, 2005; Cramer, 1968; De Deyne & Storms, 2015; Deese, 1965; Fitzpatrick et al., 2013). For example, comparisons of the data from word association tasks and large corpus-based methods show various qualitative differences in their content, showing that different forms of data collection strategies tap into various aspects of how people's knowledge is organized (e.g., De Deyne et al., 2016; Mollin, 2009). Moreover, these paradigms also suffer from a lack of consistency between studies, deficiencies in the assessment of the validity of some of the instruments used, and various other methodological issues (Canessa et al., 2020; Fitzpatrick et al., 2013). Most importantly, assuming that the construction of mental representations is ad hoc and situated means that the setting in which the task takes place constrains the type of responses that become available, due to the activation of particular situated knowledge (e.g., sitting in front of a computer to get some money). These observations reveal the need for cementing research on robust theories of language and mental representation (in this case, LASS). They also highlight the importance

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[88] While various reviews of the literature on word associations were written in the sixties and seventies (e.g., Cramer, 1968; Deese, 1965), the multiplicity of fields that use word associations as a source of information today is currently so large, that a complete review of all of its forms is beyond the scope of this research (for a recent review in the field of linguistics, see Thwaites, 2018).

[89] Also known as property generation (e.g., Santos et al., 2011).

[90] Sometimes referred to as controlled association test (e.g., Cramer, 1968).

of using measures, procedures, and analytical tools validated in previous research, providing detailed and transparent descriptions of all the steps taken during the methodology, and trying to replicate the studies. I try to tackle these issues throughout the rest of this chapter.

6.2. Literature Review

Production tasks such as word association have been used in previous studies to assess the processing, content, and structure of knowledge of people from different backgrounds. First, a limited number of studies have observed different forms of conceptual processing in people with different degrees of skill. A study by Roversi et al. (2013) showed that people from different professional backgrounds and degrees of experience (i.e., students, law graduates, law professionals, researchers) produce different combinations of linguistic and simulated responses to abstract and concrete categories in a property generation task. A similar study by Borghi et al. (2016), using a definition task[91], found that participants with different kinds of expertise in a particular domain (i.e., safety and security at the workplace) responded with different degrees of introspective and situational (i.e., simulation) and taxonomic (i.e., linguistic) content. These studies suggest the differentiated activation of conceptual systems (linguistic or simulated) when processing a categories by people with different levels of skill in a specific domain.

Other studies have used word associations to compare the content of knowledge by people with different levels of expertise. Language researchers have used cue-response pair classifications such as grammatical type (e.g., Deese, 1965), syntagmatic vs paradigmatic responses (e.g., Jenkins, 1954), or developed new coding schemes to capture qualitative differences in the way that people with different levels of language expertise make word associations (e.g., Fitzpatrick, 2006; Zareva, 2007). Other studies have assessed the performance of participants with different degrees of expertise to categories such as 'health' and 'living cell' using continued word association tasks (e.g., Colgan & McGuinness, 1998; Kostova, 2008). These studies have used measures of frequency, such as response availability and idiosyncratic responses, to capture the different degrees of proficiency and content that each of the different levels of expertise confers in a particular domain.

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[91] Definition tasks ask participants to define a term, responses which are then content analysed for differences in domains. These are a kind of production task in line with word associations.

Studies in this area have also compared the structure of knowledge in participants with different backgrounds. For example, Crowe and Prescott (2003) observed differences in the structure of knowledge in children from different age groups using clustering techniques. More recently, a series of studies by Mazzuca, Majid et al., (2020) and Mazzuca, Borghi et al., (2020) used similar techniques to compare the responses of different groups in a property generation task. In their first study, the authors observed several qualitative differences in responses to the word 'gender' by normative and non-normative individuals (Mazzuca, Majid et al., 2020). The second study observed differences in the production norms to the same word from individuals coming from three countries: Italy, the Netherlands, and the UK (Mazzuca, Borghi et al., 2020). These structural differences were ascribed to differences in both personal and cultural experiences.

It is also worth mentioning that a few studies have investigated the representation of emotion words using production paradigms such as word associations. Altarriba et al. (1999) compared the results of a word association task between emotion, concrete, and abstract words. These authors observed that emotion words received overall more association types. Word association tasks have also been used to explore the content of the mental representation emotion-laden words such as 'aesthetic' (Jacobsen et al., 2004) and emotion words such as '*Ergriffenheit'* (Kuehnast et al., 2014) in German and '*xoshbaxti'* in Persian (Sharifian & Bagheri, 2019). These studies provide evidence of the richness of the knowledge content for specific emotion words across individuals. Finally, Boiger et al. (2013) observed cross-cultural differences in the content of word associations done in the United States and Belgium for words related to anger and shame. Their results show that while both people in the United States and Belgium associate anger with aggression, Belgians also associated it to a larger extent with containment. Similarly, Belgians associated shame with both suppression and closeness to a larger extent than people in the United States, who mostly associated it with avoiding this negative experience. This last study is, to my knowledge, the only one that has shown differences in conceptual knowledge of emotion across cultural settings using production norms from word associations.

Together, these studies suggest the potential of using word association tasks to assess people's conceptualization of emotion categories (e.g., Kuehnast et al., 2014), and to investigate differences in conceptualization in people with different cultural experiences (e.g., Boiger et al., 2013) and degrees of skill with such categories (e.g., Borghi et al., 2016). Whether it is looking at the processing of a representation (e.g., Roversi et al., 2013), the content of such representations (e.g., Kuehnast et al., 2014), or the structure of those representations (e.g., Mazzuca, Borghi et al., 2020; Mazzuca, Majid et al., 2020; see also, Mazzuca, 2020), production tasks such as word association can be utilized to capture different features of people's conceptual knowledge of a category – in this case, the emotion category 'awe'. The studies in this chapter are the first to attempt to capture differences in conceptual skill with this emotion category in people with different levels of engagement with the culture of science communication.

6.3. Study 1 - Simulated vs linguistic responses in word association (60 seconds)

When people read or hear the word 'awe', a distributed network of lexical forms and a partial multimodal simulation of conceptual knowledge activate (Barsalou et al., 2008; Santos et al., 2011; Vigliocco et al., 2009). The former forms a quick and relatively shallow linguistic representation of associated words while the latter is a slower multimodal simulation of the category. First, the lexical form spreads through a linguistic network activating other lexical content that serves as cues, pointers, or shortcuts, and contribute to conceptual processing (Connell, 2019). In parallel to this process, the simulation system aggregates previously stored-in-memory multimodal knowledge and integrates the different situational elements (i.e., external and internal), in relation to the demands of the current situation to support action (Barsalou, 2009, 2016; Lebois et al., 2015). The lexical and simulation systems dynamically constitute a mental representation of *awe* (i.e., an *awe* concept) as a function of a person's past experiences with the emotion category and the affordances of the context where the activation takes place (Barrett et al., 2014).

The ability to construct the concept *awe* is in part based on the experience a person has had with this emotion through their lifespan. People who experience this emotion recurrently should be able to construct a deep multimodal representation of the category more easily (Hoemann, Nielson et al., 2020). Their simulation system should activate with greater efficiency, constructing the perceptual, affective, motor, mental, motivational, and the rest of the situational components that constitute the core content of a mental representation (Barsalou et al., 2008, 2018). I argue that responses to a production task such as word association should account for this skill to better represent the simulated elements of a mental representation and produce more words for features such as the external objects, introspective properties, and actions. Similarly, responses derived from the simulation system should also be more distinctive, as these represent the idiosyncratic experience of the individual. By contrast, I argue that people who do not conceptualize awe often will rather rely on quick language-based heuristics which carry statistically recurrent content (i.e., stereotypical). Hence, the production norms of people with different levels of expertise with this emotion should differ in the way in which the simulation and linguistic systems are activated, with experts processing a category using a multimodal simulation more readily and non-experts relying more on linguistic cues.

Evidence suggests that people closer to the culture of science communication experience this emotion more frequently (Gottlieb et al., 2018). I argue this is the result of the acculturation received from this emotion being valued in the culture of science communication. People who participate in this cultural space have more experiences with this emotion category than people who do not. The knowledge acquired through these experiences should manifest in their processing ability to represent this category using a multimodal simulation rather than using linguistic heuristics. Using a continued word association task as a means of capturing the activation of people's representational systems, I test the following two hypotheses:

Hypothesis 1: The more people engage with the culture of science communication, the fewer responses they will produce derived from the linguistic system to the cue word 'awe'.

Hypothesis 2: The more people engage with the culture of science communication, the more responses they will produce derived from the simulation system to the cue word 'awe'.

I use two sets of measurements to stand for the activation of simulated and linguistic systems. First, are measures of stereotypy and idiosyncrasy derived from the production norms, whereby the former stands for linguistic and the latter for simulated. The second set of measures are derived from a content analysis of response type categorization in which each cue-response pair is coded as either linguistic or simulated.

I expect to find that the more people engage with this cultural space, the more responses derived from the simulation system and the fewer linguistic responses they will produce.

Guided by the principle of transparency (see Fitzpatrick et al., 2013), in the next sections I describe in detail the design, participants, and processing of the data they produced.

6.3.1. Procedure

To test these hypotheses, I used a continued free association task formalized by Noble (1952) and used by de Groot (1989) and more recently by Kenett et al. (2011). This simple task consists of giving participants one minute after receiving a cue word to produce as many word associations as possible. Studies using word associations have shown the differentiated activation of the linguistic and simulation systems during the task (De Deyne & Storm, 2008a; Wu & Barsalou, 2009).

Participants were contacted through Amazon's Mechanical Turk (MTurk). They were told they would participate in a word association and survey study. On reading the information sheet and completing the informed consent form (appendix J), participants received the instructions (appendix K) for the free association task. These instructions were adapted from Kenett et al. (2014) and Fitzpatrick (2013). Participants saw the cue word in the centre of the screen highlighted in boldface and empty spaces where they could write the associates as they came to mind. On writing a response and pressing enter, the cursor jumped to the next blank space where they could write a new association. Participants had 60 seconds to complete the task for each cue word. Every participant completed the task on two practice words, the target word 'awe', and a filler word. After completing the task, participants were thanked and then instructed to complete the questionnaires.

Two questionnaires captured their engagement with science communication. First, they responded to the 10-item instrument developed by Füchslin et al. (2018) to capture their overall perceptions of science (appendix L). Then they responded to the consumption of science communication scale (appendix M)[92]. I also included two one-question religiosity and spirituality items (appendix N). Lastly, I included six questions about the participants' sociodemographic characteristics, such as gender, age, ethnicity, and political persuasion, all of which are common in survey research (appendix O). After completing the questionnaires, the participants responded to an honesty question about whether they were paying attention

[92] I developed the consumption of science communication scale as a side project. Its development is presented in appendix P and Q.

and answered the questionnaire truthfully or not (Rouse, 2015). They were then thanked, debriefed, and received the code through which they requested their payment. The task and survey were prepared using Qualtrics (2019) and posted through Turkprime/Cloudresearch (Litman et al., 2017) to MTurk.

The data produced were pre-processed in two steps: exclusions and standardization. Then I processed it in two stages: response type classification and measure construction. I classified cue-responses for the target word using a modified version of the taxonomic coding scheme used to separate between lexical and simulated content in previous work (De Deyne & Storms, 2008a; Santos et al., 2011; Wu & Barsalou, 2009). Then I tallied up idiosyncratic, stereotypical, simulated, and linguistic responses for each participant. After processing the information, I tested the hypothesis using regressions analysis.

6.3.2. Sample

A convenience sample (*N* = 306) were recruited through Amazon's Mechanical Turk service in exchange for 1.50USD compensation. All participants were based in the United States, over 18 years of age, and native English speakers. Evidence suggests that participants recruited through this service are more representative of the United States population than other internet and student samples (Buhrmester et al., 2016).

I identify four a priori criteria to manually exclude participants from the sample (n = 47). Some of these criteria follow the benchmarks used by de Deyne et al. (2019) and the best practices for post-hoc identification of meaningless or poor-quality data offered by Dunn et al. (2018). The criteria were:

1) Participants who replied affirmatively or with spam to an honesty question (9 exclusions).
2) Participants who failed to follow the word association instructions. This included those who did not produce any word associations for the target word, wrote the same words over and over, wrote sentences, or replied nonsense (15 exclusions)
3) Careless responses: Dunn et al. (2018) recently proposed an easy to use and simple statistical method to catch careless responses called the intra-individual response variability index for strings (IRV). Low IRV indicate that people are responding with only one rating to all survey questions (i.e., straightlining). Participants with very low

IRV scores for the consumption questionnaire (below 5 percentile) were removed (19 exclusions).

4) Extreme response outliers: Participants who produced more than 20 responses (3*IQR of total responses) (4 exclusions).

Two hundred and fifty-nine participants remained after the exclusion criteria were applied. Table 6.1 shows the demographic characteristics of the final sample.

Table 6.1
Demographic Characteristics of Participants (n=259)

Baseline characteristic	n	%
Gender		
female	117	45.2
male	140	54.1
other	2	0.8
Education Attainment		
High school diploma or equivalent	36	13.9
Some college	88	34
Bachelor's degree or equivalent	111	42.9
Master's degree or equivalent	18	6.95
Doctoral or professional degree	6	2.32
Ethnicity		
African American or black	30	11.6
Hispanic, Latin American or Latinx	11	4.25
White or European American	205	79.2
Other	13	4.95

6.3.3. Ethical considerations

The study received category B approval from the Human Ethics Committee of the University of Otago #D19/374 (appendix R).

6.3.4. Materials

The study includes the free word association task, a 10-item questionnaire on public perceptions of science, the science communication consumption scale, spirituality and religious measures, and a sociodemographic questionnaire.

1) Free Word Association Tasks

For this study, each participant performed a continued free word association task on two practice words, one target word, and a filler word. Practice words are important in this type of task to guarantee that the participants understood the instructions and become familiar with the task. I included a filler word as a distraction from the purpose of the study.

The critical word 'awe' is the emotion category at the centre of this investigation. The word is for the most part used as a noun, as in the sentence 'She filled the audience with awe'. This word appears relatively infrequently in the English language, scoring a 2.63 out of 100 in the contextual diversity measure ($SUBTL_{wd}$) and ranked 9,846 in Brysbaert and New's (2009) American English Frequency norms[93]. It also received a mean score of 1.89 in a ranking of 1 (not concrete) to 5 (concrete) in Brysbaert et al. (2014), making it a highly abstract category.

The two practice words scored high on concreteness and the filler scored low on this metric. The three words were matched for frequency, between the 8,000 and 10,000 most frequent words (Brysbaert & New, 2009). Most importantly the three words were chosen as they scored very low on similarity ratings to the word 'awe'[94]. Similarity ratings were calculated using the Python tool *Spacy* (Honnibal & Montani, 2017) which has a function that calculates a similarity rating from 1 million-word vectors. The three chosen words for this task were 'ferry', 'toaster', and 'rebound'.

Table 6.2
Words in Word Association Task

Words	$SUBTL_{wd}$	Frequency rank	Concreteness	Relatedness to awe
'ferry'	5.35	8162	4.59	0.03
'toaster'	3.88	8607	4.37	0.09
'rebound'	2.78	9111	2.41	0.08
'awe'	2.63	9846	1.89	

2) 10-item survey on public perceptions of science[95]

Schäfer et al. (2018) collected data of perceptions of science in the Science Barometer Switzerland using a 30-item survey. Their questions were taken from a comprehensive literature review of previous studies on attitudes towards science, trust in science, science literacy, belief in science, and science media consumption (e.g., BBVA Foundation, 2011; Tsfati et al., 2010). Füchslin et al. (2018) narrowed this extensive questionnaire to create a

[93] The norms include more than 60,000 English Lemmas taken from the subtitles of 8,388 television shows and movies. The authors found the score of contextual diversity ($SUBTL_{cd}$) to be the best measure of frequency in their analysis, hence words were ranked according to this measure.
[94] The score goes from 1 (the same word) to 0 (completely dissimilar).
[95] The data from this section of the survey was not used in this study.

10-item survey that captures the many aspects of people's relation to science and has similar predictive power.

3) Consumption of science communication scale

Participants responded to the consumption of science communication scale that I developed and validated (appendix P and Q), and which includes eleven questions about their engagement with products or situations where they encounter science communication.

4) Spirituality and religiosity test

I included two one-item self-report questions about people's religiosity and spirituality taken from Saslow et al., (2013). This was a response to studies suggesting a connection between religiosity and spirituality with awe (e.g., Krause & Hayward, 2014; Van Capellen & Saroglou, 2012).

5) Demographic questionnaire

Lastly, I included six demographic questions to control for certain factors that might influence people's representation of any category. This included measures for age, gender, ethnicity, level of education, political orientation, and religious affiliation.

6.3.5. Processing

1) Standardization

Words were standardized by hand using various steps taking inspiration from other studies (e.g., De Deyne et al., 2019; De Deyne & Storms, 2008b; Fitzpatrick et al., 2013; Kenett et al., 2014) and following these steps:

1) All words were turned into lowercase.
2) The last responses a person produced where the meaning was impossible to deduce (e.g., rec, in, e, i) were removed (13 words).
3) The last response a person produced where the meaning could be determined was completed (e.g., skateboar → 'skateboard', creativit → 'creativity', univer → universe) (12 words).
4) I corrected the spelling when there were typos. We used US spelling based on the Merriam Webster Dictionary (e.g., amasement → 'amazement', awarness → 'awareness', aweful → 'awful', drinkgs → 'drinks') (52 words).

5) Numbers were turned into word form (e.g., 7 wonders → 'seven wonders') (2 words).
6) Indefinite and definite articles were removed (e.g., the universe – 'universe') (2 words).
7) Prepositions 'in' and 'of' were removed (e.g., in love, look of) (5 words).
8) Commas, periods, and other punctuation marks (except for hyphens were removed) (1 word).
9) I separated long strings (e.g., sound for something → 'sound' / 'something') (3 words), adjective-noun pairs (heartfelt performance → 'heartfelt' / 'performance', new baby → 'new'/ 'baby') (8 words) and strings joined by coordinating conjunctions (or, and) (good or bad → 'good'/ 'bad', life and death → 'life'/ 'death') (3 words).
10) Space and hyphens[96] were turned into underscores (e.g., mind-blown → mind_blown, jaw-dropping → jaw_dropping).
11) The strings 'seeing something new' and 'seeing something unexpected', made by one participant were turned into four words 'seeing' / 'something' / 'new' / 'unexpected'.
12) Finally, when the same word was produced more than once, the second one was removed (5 words).

After standardizations, there were 2015 tokens and 653 types.

2) Response type categorization

Cue-responses pairs were coded using a simplified and adapted version of the taxonomy developed in Cree and McRae (2003) and used by De Deyne and Storm (2008a), Wu and Barsalou (2009), and others. This kind of taxonomy allows for the categorization of items in relation to the activation of either the linguistic or simulation systems (e.g., Santos et al., 2011). The version used here consists of six categories: lexical, taxonomic, entity, external situational, introspective, and miscellanea.

3) Dependent variables

I constructed four count measures for the analysis of the word association data based on previous work.

[96] This was done because the 'tidytext' (Silge & Robinson, 2016) functions used to separate strings split all words that use hyphens.

1) *Stereotypy score* **(stereotypical):** Stereotypical responses were defined as the dominant responses in the production norms that resulted from this task (de Groot, 1989; Fitzpatrick et al., 2013). A stereotypy norms list was constructed out of the responses produced by at least 5 per cent of all participants (i.e., 13 responses). Then the participants received a point for every stereotypical word they produced. This measure of stereotypy captures the activation of the linguistic system in conceptual processing.
2) *Idiosyncratic responses* **(idiosyncratic):** The total number of unique types per cue produced. These idiosyncratic responses, also called hapax legonomena (De Deyne et al., 2019), have been used in previous work as measures of heterogeneity of the content of people's knowledge (e.g., Cramer, 1968). I argue that this measure of idiosyncrasy captures the construction of a simulation in conceptual processing.
3) *Total number of linguistic responses* **(linguistic):** The sum of the total number of taxonomic and lexical associates that a person produced corresponding to the activation of the language representational system. Research shows that early responses in word associations are usually of this kind (De Deyne & Storms, 2008a) and that people produce more linguistic responses in word associations than in property generation and imageability tasks (Wu & Barsalou, 2009).
4) *Total number of simulated responses* **(simulated):** The sum of the entities, external situational, and introspective features produced by each participant corresponding to the activation of a simulation. Previous findings indicate that these are the most common response types produced by participants after a few rounds (De Deyne & Storms, 2008a), and that imageability and property generation tasks get people to produce more of these (Wu & Barsalou, 2009).

4) Independent Variable

The main independent variable is the mean value of responses to the items of the consumption of science communication scale **(consumption)**. This measure captures people's engagement with science communication by measuring their consumption behaviour around this cultural space.

5) Covariates

Age **(age),** level of educational attainment **(education),** and spirituality **(spirituality)** were included as covariates. Age and level of education effects in word association tasks have been documented in the literature (e.g., Cremer et al., 2010; Hirsh & Tree, 2001; Rosenzweig, 1964). Spirituality was included to capture other cultural values that might be associated with awe (e.g., Krause & Hayward, 2015; Sundararajan, 2002; Van Cappellen & Saroglou, 2012). Religiosity was not included as it is correlated highly with spirituality ($\rho = 0.64$, $p < 0.01$). Despite being ordinal factors, level of educational attainment and level of spirituality were treated as continuous variables to simplify interpretation. This is common practice in social science research and can be justified statistically in many situations, particularly when there are no major differences between the model with factors and the model with a continuous variable (Pasta, 2009). Other demographic factors such as gender, ethnicity, and political orientation were not included, to streamline the analysis. Table 6.3 presents the descriptive statistics and correlations of all variables. As expected, simulation and idiosyncratic responses, as well as linguistic and stereotypical show a high level of correlation.

Table 6.3

Means, Standard Deviations, and Correlations with Confidence Intervals of Variables (n = 259)

Variable	*M*	*SD*	1	2	3	4	5	6	7
1. stereotypical	2.96	1.51							
2. idiosyncratic	1.58	1.86	-0.09						
			[-.21, .03]						
3. linguistic	3.23	1.8	.68**	-0.07					
			[.61, .74]	[-.19, .05]					
4. simulated	4.53	3.39	0.03	.67**	-.28**				
			[-.09, .15]	[.60, .73]	[-.39, -.16]				
5. consumption	2.81	0.8	-0.11	0.04	-0.13	0.08			
			[-.23, .02]	[-.09, .16]	[-.25, -.01]	[-.05, .20]			
6. age	38.35	12.16	0.02	0.07	-0.14	0.17	-0.01		
			[-.10, .14]	[-.05, .19]	[-.26, -.02]	[.04, .28]	[-.13, .11]		
7. education	2.5	0.9	-0.07	0.12	-0.06	0.03	.29**	.15*	
			[-.19, .06]	[-.00, .24]	[-.18, .06]	[-.09, .15]	[.17, .40]	[.03, .27]	
8. spirituality	2.81	1.54	-0.1	0.03	-0.12	-0.06	-0.01	.25**	-0.01
			[-.22, .02]	[-.09, .15]	[-.24, .00]	[-.18, .06]	[-.13, .11]	[.14, .36]	[-.13, .11]

Pearson's correlations with p values adjusted for multiple comparisons using Holm-Bonferroni method (Holm, 1979).
$*p < 0.05$, $**p < 0.01$

6.3.6. Intercoder reliability

A second coder and I went through all the cue-response pairs, classifying them using the coding scheme. The coder attended a two-hour-long training session where we went through each of the categories and practised using various examples. The coder then received an excel spreadsheet with all unique responses to the word 'awe' and the instructions of how-to code for these (appendix S). The coder was instructed to only use one code for each category. After the initial meeting, we met to discuss some of the difficulties that the coder found during coding. Intercoder reliability assessment for the response type categorization was substantial (Cohen's $\kappa = 0.62$) (Landis & Koch, 1977). Diverging codes were resolved through consensus during a final debriefing session.

6.3.7. Results and discussion

To test the proposed hypotheses, where people with different levels of consumption of science communication exhibit different levels of production of responses from the language and simulation systems, I performed regression analysis for count data (positive integer, positively skewed distributions, and relatively infrequent discrete events) using the 'stats' package in R (R Core Team, 2013). The analysis of count data is usually done using the family of regressions that assume Poisson or negative binomial distributions (Coxe et al., 2009). Poisson regression is used when the mean and variance are assumed equal or close to equal. In cases when this assumption did not hold, I used a negative binomial regression.

Table 6.4 shows the results of regressions on the four measures. Stereotypical, idiosyncratic, and simulated responses were not significantly related to the consumption of science communication ($b = -0.6$, $SE = .05$, $p = 0.205$), ($b = 0.0005$, $SE = .09$, $p = 0.99$), ($b = 0.08$, $SE = .06$, $p = 0.21$) respectively, although the direction of the coefficients is consistent with my prediction.

The model for linguistic responses suggests a small yet significant effect on this variable by people who consume science communication, who overall produced fewer linguistic responses ($b = -0.09$, $SE = .05$, $p = 0.044$). This result suggests that those who consume more science communication rely less on their language system to conceptualize awe.

The consumption variable only shows significant effects in the model for linguistic responses. The incidence rate ratio for this model predicts that a unit increase in the consumption of science communication scale produces a 9% decrease in the number of linguistic responses. Keeping everything else constant, the model predicts that a person with the highest possible score in the consumption of science communication scale (i.e., cons = 5) produces 1.52 fewer linguistic responses than a person who does not engage with science communication at all (i.e., cons = 1). This result, while modest, suggests the differentiated activation of the representational systems when conceptualizing 'awe' by people with different degrees of engagement with science communication.

Table 6.4
Results of Multiple Regression Analysis (n=259)

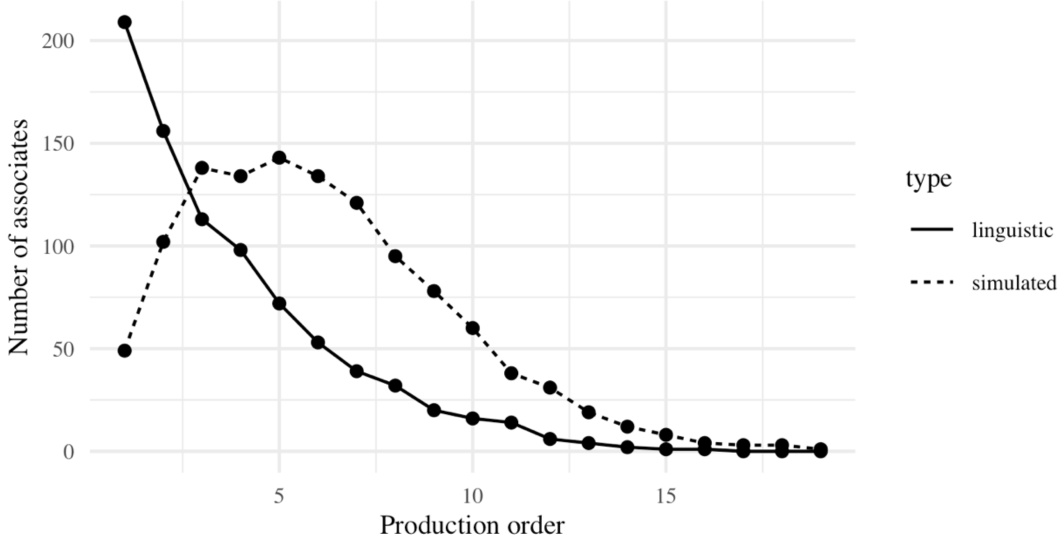
Stereotypical Responses - Poisson				
Predictor	*Estimate*	*SE*	*Exp(b)*	*95% CI, Exp(b)*
Intercept	**1.34****	0.19	3.81	2.65 – 5.48
consumption	-0.06	0.05	0.94	0.86 – 1.03
age	0	0	1	1.00 – 1.01
education	-0.03	0.04	0.97	0.89 – 1.06
spirituality	-0.04	0.02	0.96	0.92 – 1.01
Idiosyncratic Responses - Negative binomial				
Intercept	-0.15	0.36	0.87	0.44 – 1.71
consumption	0	0.09	1	0.84 – 1.19
age	0	0.01	1	0.99 – 1.02
education	0.14	0.08	1.15	0.99 – 1.35
spirituality	0.01	0.05	1.01	0.92 – 1.11
Linguistic Responses - Poisson				
Intercept	**1.74****	0.18	5.68	4.01 – 8.05
consumption	**-0.09***	0.05	0.91	0.84 – 1.00
age	-0.01	0	0.99	0.99 – 1.00
education	0	0.04	1	0.92 – 1.08
spirituality	-0.03	0.02	0.97	0.92 – 1.01
Simulated responses - Negative binomial				
Intercept	1.01	0.25	2.76	1.70 – 4.47
consumption	0.08	0.06	1.08	0.96 – 1.22
age	**0.01****	0	1.01	1.00 – 1.02
education	-0.01	0.06	0.99	0.88 – 1.10
spirituality	-0.06	0.03	0.94	0.88 – 1.00
*$p<0.05$, **$p<0.01$				

Importantly, the LASS (Barsalou et al., 2008) suggests that in the first few seconds of activity, people use the language system to produce a quick heuristic response to a word association. After a few seconds (~7.5s), the simulation activates, and people begin to represent entity, external, and introspective features of a category. As figure 6.1 shows, the first two associates produced by most participants were linguistic responses. The aforementioned results suggest that those who consume more science communication and produce less linguistic responses are activating their simulation system earlier than those who don't engage with this cultural space.

However, from the third response onward, most participants produced more simulated than linguistic responses. Considering that, on average, participants took 7.8 seconds to write a word, by around the 15-second mark, most participants were already producing associates using a simulation of *awe*. The long generations period (i.e., 60 seconds) gave all participants enough time to produce all sorts of responses irrespective of their relationship to science communication. That most participants produced both stereotypical and idiosyncratic responses is indicative of the prevalence of the word 'awe' in the broader culture and people generally having had some personal experience with this emotional category. To tackle these issues, study 2 repeats this study but with a shorter time frame (i.e., 15 seconds).

Figure 6.1

Production Order of Linguistic and Simulated Responses (n=259)



6.4. Study 2 - Simulated vs linguistic responses in word association (15 seconds)

Study 2 repeats the first study using the same procedure but giving participants a shorter time frame to produce word associations (15 seconds). A different and larger convenience sample was drawn from MTurk, and the same two hypotheses were tested. My goal was again to test whether people's processing abilities in the conceptualization of awe are a function of their level of engagement with science communication.

6.4.1. Procedure

The procedure was identical to study 1, with the one difference that participants had fifteen seconds rather than sixty per word during the word association task.

6.4.2. Sample

A new sample of five hundred and eight ($N = 508$) participants was recruited in the month of May 2020 through Amazon's Mechanical Turk in exchange for 0.75USD compensation. All participants were based in the United States, over 18 years of age, and native English speakers. I used the same four a priori criteria to exclude 115 participants from the final sample for analysis.

1)Participants who failed the honesty question (25 exclusions)
2)Participants who did not follow instructions (72 exclusions)
3)Participants who produced careless responses to the consumption of science communication scale (below 5 percentile IRV scores) (18 responses)
4)Extreme response outliers: No participants were excluded as extreme outliers (3*IQR for total responses).

Three hundred and ninety-three participants remained after the exclusions were applied. Table 6.5 shows the demographic characteristics of the final sample.

Table 6.5
Demographic Characteristics of Participants (n=393)

Baseline characteristic	n	%
Gender		
female	184	46.8
male	208	52.9
other	1	0.3
Education Attainment		
Some high school	3	0.8
High school diploma or equivalent	34	8.65
Some college	93	23.7
Bachelor's degree or equivalent	184	46.8
Master's degree or equivalent	65	16.5
Doctoral or professional degree	14	3.56
Ethnicity		
African American or black	43	10.9
Hispanic, Latin American or Latinx	34	8.65
White or European American	274	69.7
Other	42	10.75

6.4.3. Ethical considerations

This study was approved by the Human Ethics Committee of the University of Otago #D20/152 (appendix T).

6.4.4. Materials

Participants performed the continued word association task with the same practice ('ferry', 'toaster'), target ('awe'), and filler ('rebound') words for 15 seconds for each word. They then responded to the 10-item survey on public perceptions of science (Füchslin et al., 2018), the consumption of science communication scale, the spirituality and religiosity test, and the demographics questionnaire.

6.4.5. Processing

1) Standardization

All words were again manually standardized following the same procedure as in the previous study[97]. After processing there were a total of 1434 tokens and 418 types.

2) Response type categorization

Of the 418 types produced as responses to the word 'awe' in this new study, 190 were different from those in the previous study. I coded these new cue-pair responses following the simplified version of the taxonomy used in the previous section. Given that more than half of the types (228) had already been coded in the previous section, a second coder was not required to perform intercoder reliability checks.

3) Variables

I tested the hypothesis with the same four independent variables stereotypical (**stereotypical**), idiosyncratic (**idiosyncratic**), linguistic (**linguistic**), and simulated (**simulated**) responses. The main dependent variable was again the score from the consumption of science communication scale (**consumption**) and the covariates were age

[97] All words were turned into lowercase. Then all the last responses a person produced where the meaning was impossible to deduce were removed (51 words). A person's last response where the meaning could be determined was completed (34 words). Spelling was corrected when the word was obvious following American spelling based on the Merriam Webster Dictionary (38 words). Numbers were turned into word form (1 word). Indefinite or definite articles were removed (1 word). Prepositions 'of' and 'in' was removed (2 words). Adjective noun strings were separated (2 words). Strings joined by a coordinating conjunction (and, but, or) were separated (1 word). Spaces and hyphens were turned into underscores. Finally, when the same word was repeated, the second time was removed (3 words).

(**age**), level of education (**education**), and spirituality (**spirituality**). Table 6.6 shows the descriptive and correlations of the dependent, independent, and covariates variables.

Table 6.6
Means, Standard Deviations, and Correlations with Confidence Intervals of Variables (n = 393)

Variable	*M*	*SD*	1	2	3	4	5	6	7
1. stereotypical	1.48	1.12							
2. idiosyncratic	0.69	0.94	-.29**						
			[-.38, -.20]						
3. linguistic	2.06	1.33	.74**	-.18**					
			[.70, .78]	[-.27, -.08]					
4. simulated	1.57	1.5	-.13	.57**	-.31**				
			[-.23, -.04]	[.50, .63]	[-.40, -.22]				
5. consumption	2.93	0.87	-0.12	0.06	-0.14	0.03			
			[-.22, -.02]	[-.04, .15]	[-.24, -.04]	[-.07, .13]			
6. age	36.6	11.65	-.14	-0.06	-.20**	-0.04	-0.08		
			[-.23, -.04]	[-.15, .04]	[-.29, -.10]	[-.14, .06]	[-.18, .01]		
7. education	3.8	0.96	0.06	-0.01	0	0.04	0.26**	0.09	
			[-.04, .15]	[-.11, .09]	[-.10, .10]	[-.05, .14]	[.16, .35]	[-.01, .19]	
8. spirituality	2.83	1.44	-.20**	0	-.21**	-0.03	0.12	0.14	0.03
			[-.29, -.10]	[-.10, .09]	[-.30, -.11]	[-.13, .07]	[.02, .22]	[.05, .24]	[-.07, .13]

Pearson’s correlations with p values adjusted for multiple comparisons using Holm-Bonferroni method (Holm, 1979).
$^{*}p < 0.05$, $^{**}p < 0.01$

6.4.6. Results and discussion

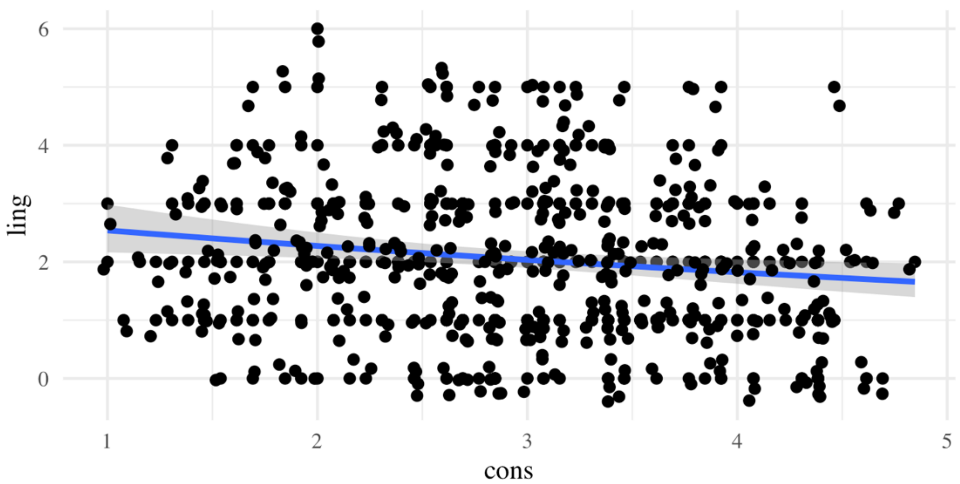
I tested the same hypotheses as in the first study of this chapter using regression analysis for count variables using the ‘stats’ package in R (R Core Team, 2013). Table 6.7 shows the result of the regressions for stereotypical, idiosyncratic, linguistic, and simulated responses. The results show that people who engage more with science communication produced overall fewer stereotypical (b = -0.12, SE = .05, p = 0.015) and linguistic (b = -0.12, SE =.04, p = 0.007) responses for the word ‘awe’. Figure 6.2 shows the decrease in linguistic responses as a function of an increase in the consumption of science communication scale. As in the previous study, these small but significant effects suggest a differentiated activation of the linguistic system for the different levels of engagement with science communication, with those who engage more with this cultural space using this system less to construct a mental representation of ‘awe’.

Table 6.7
Results of Multiple Regression Analysis (n=393)

Stereotypical Responses - Poisson				
Predictor	*Estimate*	*SE*	*Exp(b)*	*95% CI, Exp(b)*
Intercept	**0.98****	0.24	2.66	1.67 – 4.25
consumption	**-0.12***	0.05	0.88	0.80 – 0.98
age	**-0.01***	0	0.99	0.98 – 1.00
education	0.09	0.04	1.09	1.00 – 1.19
spirituality	**-0.09****	0.03	0.92	0.87 – 0.97
Idiosyncratic Responses - Negative binomial				
Intercept	-0.29	0.39	0.75	0.34 – 1.61
consumption	0.09	0.08	1.1	0.94 – 1.29
age	-0.01	0.01	0.99	0.98 – 1.01
education	-0.03	0.07	0.97	0.84 – 1.12
spirituality	-0.01	0.05	0.99	0.90 – 1.09
Linguistic Responses - Poisson				
Intercept	**1.5****	0.2	4.5	3.03 – 6.68
consumption	**-0.12****	0.04	0.89	0.82 – 0.97
age	**-0.01****	0	0.99	0.98 – 0.99
education	0.04	0.04	1.04	0.97 – 1.13
spirituality	**-0.07****	0.03	0.93	0.89 – 0.98
Simulated responses - Negative binomial				
Intercept	0.38	0.28	1.46	0.84 – 2.51
consumption	0.02	0.06	1.02	0.91 – 1.14
age	0	0	1	0.99 – 1.01
education	0.05	0.05	1.05	0.94 – 1.16
spirituality	-0.02	0.03	0.98	0.92 – 1.05

*p<0.05, **p<0.01

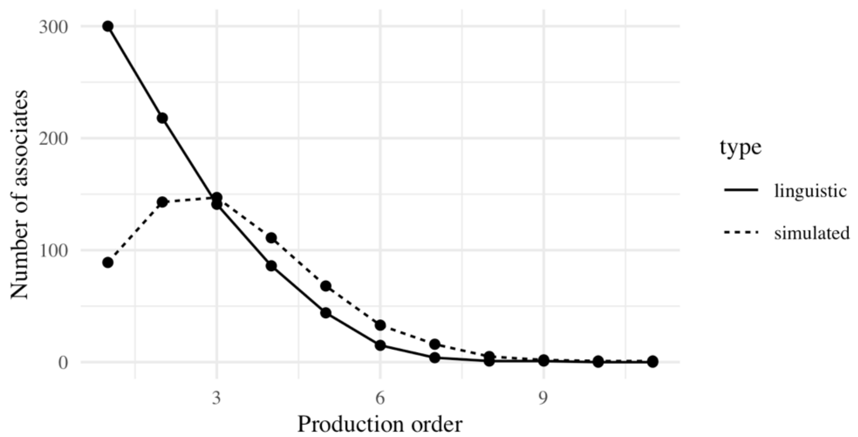
Figure 6.2
Linguistic responses against science consumption scale (n=393)



However, as in the previous study, there was no relation between simulated and idiosyncratic responses and consumption of science communication. As figure 6.3 shows, fewer people were able to generate simulated (and idiosyncratic) responses in this shorter time frame. Considering that word association privilege the activation of the linguistic system (e.g., Wu & Barsalou, 2009), the 15-second time frame might have not been long enough to allow many participants to generate a full simulation and write down the words related to this representational system. In contrast to the previous study where the long response time gave all participants enough time to activate their simulation systems, this study didn't give participants enough time to generate responses using this representational system. This might explain why despite the differentiated activation of the linguistic system for the different levels of consumption of science communication there were no differences in the activation of the simulation to represent 'awe'.

Figure 6.3

Production Order of Linguistic and Simulated Responses (n=393)



The results of the first two studies show important differences in the conceptual processing by people with different degrees of engagement with science communication. The data from both studies offers evidence that people who participate in this cultural space use their linguistic representational system less in their conceptualization of awe. Importantly, the effects for linguistic responses in the second study were more robust than those in the first study. Considering that the word association task privileges early linguistic responses over simulated (Wu & Barsalou, 2009) and that linguistic processing is done faster than the simulation (Santos et al., 2011), these results indicate that those who participate in the culture of science communication were jumping the early stages of processing using these shallow representations and engaging directly with the simulation. Assuming that the responses from the linguistic system carry very little of the semantic content of a word and serve mostly as heuristics for a deeper and richer conceptualization through the simulation system (Barsalou et al., 2008), the differences in activation suggest that those who engage with science communication have developed the conceptual skill to represent this emotion category by not relying on the linguistic system. I argue that these differences are the result of having encountered this emotion category more often while navigating the culture of science communication; a cultural space where this emotion is valued and often represented (see the previous chapter).

6.5. Study 3 - Natural kind responses

Conceptual skills should also manifest in specialized content knowledge tailored to the experiences in the specific domain where these occur (e.g., K. E. Johnson & Mervis, 1997). Because some types of awe represented in science communication are tied to the cultural mandates of naturalism and environmentalism (see Pigliucci, 2006, Sideris, 2017), the content of people's representation of this emotion in this space should reflect that interest in the natural world. Hence in this study, I test the following hypothesis:

Hypothesis 3: People who engage more with the culture of science communication will produce more natural kind responses to the cue word 'awe'.

6.5.1. Sample

The study uses the word association norms from studies 1 (n = 259) and 2 (n = 393).

6.5.2. Materials - Natural kind categorization

All responses to the cue 'awe' were coded through content analysis using a dichotomous classification based on whether these words referred to natural kinds (1) or not (0). I use a traditional definition of natural kinds which makes the distinction between natural occurring objects and human-made artefacts (Gelman, 1988). This definition includes both living agents and non-living objects such as rabbits, roots, mountains, and rainbows.

6.5.3. Intercoder reliability

A second coder went through all the 653 types produced by participants in study 1 and classified them as either natural kind or not using the instructions (appendix U). Intercoder reliability for this section (Cohen's κ= 0.87) was "almost perfect" (Landis & Koch, 1977).

Disagreements were resolved through consensus during the debrief session. The 190 unique types of study 2 were coded only by me.

6.5.4. Procedure

Every natural kind response made by every participant was summed up as a score **(natural)** which was then used as the dependent variable in count data regression analyses. The score from the consumption of science communication scale was the main independent variable, while age, education, and spirituality, were included as covariates. Table 6.8 and table 6.9 show the descriptive statistics for natural kind responses and its correlation to the other variables for both datasets respectively.

Table 6.8

Means, Standard Deviations, and Correlations with Confidence Intervals of Variable Nature (n = 259)

Variable	M	SD	cons	age	edu	spi
natural	1.04	2.09	0.09	0.13	-0.01	0.03
			[-.03, .21]	[.01, .25]	[-.13, .11]	[-.09, .16]

Pearson's correlations with p values adjusted for multiple comparisons using Holm-Bonferroni method (Holm, 1979).
$*p < 0.05$, $**p < 0.01$

Table 6.9

Means, Standard Deviations, and Correlations with Confidence Intervals of Variable Nature (n = 393)

Variable	M	SD	cons	age	edu	spi
natural	0.33	0.8	-0.02	0.02	0.03	-.14*
			[-.12, .08]	[-.08, .12]	[-.07, .13]	[-.24, -.04]

Pearson's correlations with p values adjusted for multiple comparisons using Holm-Bonferroni method (Holm, 1979).
$*p < 0.05$, $**p < 0.01$

In both studies, most participants did not produce any natural kind responses (figures 6.4 and 6.5). In situations when there are excess zeros in count data, two-part models such as the hurdle model are recommended (Mullahy, 1986). Hurdle models assume that there are two processes in people's behaviour: one modelling zeros and another modelling non-zero counts. The former frequently uses a binomial logistic distribution while the latter typically follows a Poisson or a negative binomial distribution to model the positive counts (Loeys et al., 2012). I chose the hurdle model because all participants have the potential of producing non-zero counts, meaning that there are no structural zeros. Moreover, I assumed that there are two independent processes occurring during the task. First, there is a process through which a person represents 'awe' by activating a situated simulation that includes a natural kind. After constructing this particular awe situation (i.e., passing the hurdle), the construction of related concepts that experientially correlate with the natural kind representation is facilitated (see

Barsalou et al., 2008). Thus, the first step captures the ability to conceptualize 'awe' using natural kinds and the second suggests the intensity and depth of the process. These two, I assume, are a function of the number of experiences that a person has had with such objects in situations. I will use the same main independent variable (i.e., consumption) and covariates (i.e., age, education, spirituality) for the models for both datasets.

Figure 6.4

Natural Kind Response Frequency (n=259)

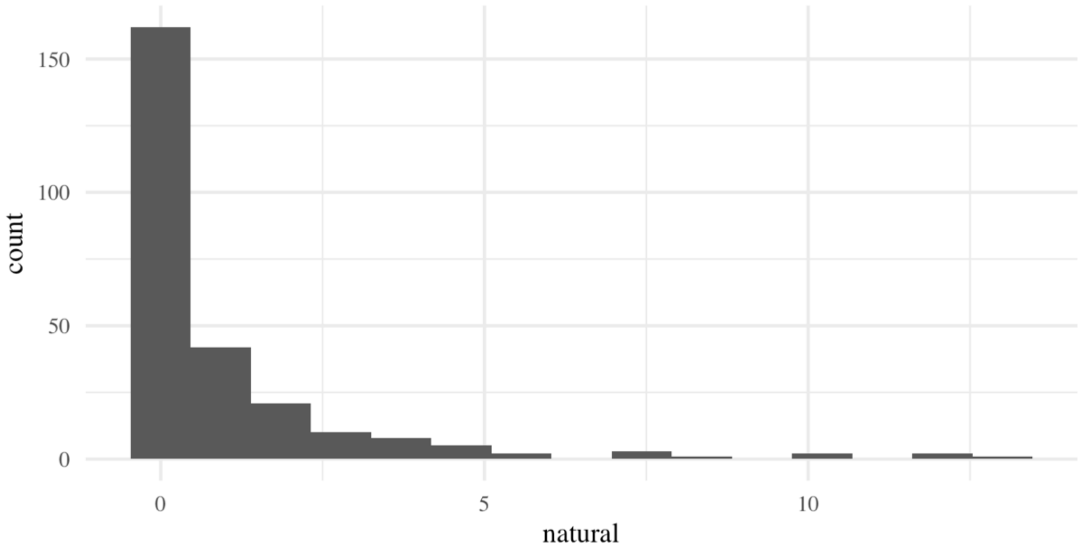
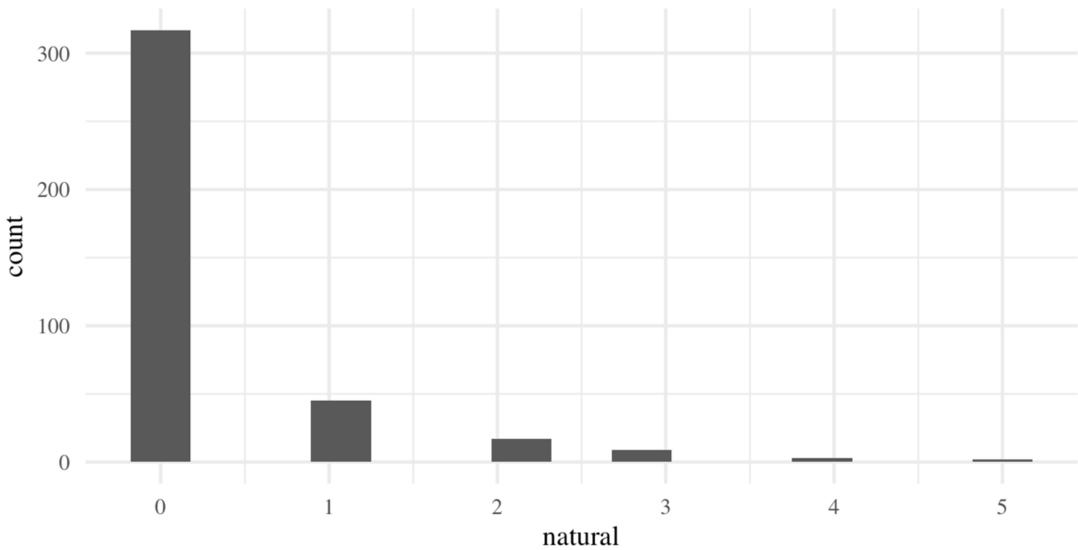


Figure 6.5

Natural Kind Response Frequency (n=393)



6.5.5. Results and discussion

Table 6.10 and table 6.11 show the results for the negative binomial hurdle model for natural kind responses. The results from the zero-hurdle model indicate that consumption of science communication doesn't increase the odds of producing a natural kind response. One thing worth noticing at this point is that a few participants read the word awe as its homophone, the interjection 'aw'.[98] This word has a very different connotation as it is used to express feelings of sympathy, cuteness, and disappointment (Oxford University Press, n.d.-b). As a result, a few participants produced associates such as 'puppy', 'cat', and other natural kind responses which are not stereotypically related to the emotion 'awe', but which are associated with this homophone. Because some of these participants read the word both as 'awe' and 'aw' it was unreasonable to remove them from the sample. However, keeping all the participants who read 'awe' as 'aw' might have created the situation where people who do not consume science communication still produce natural kind responses without necessarily representing the targeted emotion category.

Table 6.10

Results of Regression Analysis for Variable Nature (n=259)

Natural kind responses - Negative binomial hurdle model[ab]				
Zero-hurdle model				
Predictor	*Estimate*	*SE*	*Exp(b)*	*95% CI, Exp(b)*
Intercept	-0.62	0.66	0.54	0.15 – 1.97
consumption	-0.03	0.17	0.97	0.69 – 1.35
age	0.01	0.01	1.01	0.99 – 1.04
education	-0.01	0.15	0.99	0.73 – 1.33
spirituality	-0.12	0.09	0.89	0.75 – 1.06
Count model				
Intercept	-1.74	0.96	0.18	0.03 – 1.16
consumption	**0.5***	0.21	1.65	1.10 – 2.46
age	0.02	0.01	1.02	0.99 – 1.05
education	-0.2	0.17	0.82	0.59 – 1.14
spirituality	0.06	0.11	1.06	0.85 – 1.31

*$p < 0.05$, **$p < 0.01$.

[a] Comparison of predicted zeros of Poisson regression 124 against the actual zeros 162 suggests zero inflation.

[b] Likelihood ratio test comparing Poisson and negative binomial hurdle models ($\chi2$ (1) = 55.706, $p < 0.001$).

[98] It is hard to tell how many participants read 'awe' as 'aw'. For example, 17 participants from the first study produced the association 'cute', a word stereotypically related to the conjunction 'aw'. However, most of these participants who produced associates such as 'cute', 'baby', or 'puppy' also produced words such as 'amazement', 'wonder', 'some', and 'struck', suggesting that many of these interpreted 'awe' both as its intended meaning and as its homophone.

Table 6.11
Results of Regression Analysis for Variable Nature (n=393)

Natural kind responses - Poisson hurdle model[ab]				
Zero-hurdle model				
Predictor	*Estimate*	*SE*	*Exp(b)*	*95% CI, Exp(b)*
Intercept	-0.78	0.74	0.46	0.11 – 1.95
consumption	-0.26	0.16	0.77	0.56 – 1.06
age	0.01	0.01	1.01	0.98 – 1.03
education	0.16	0.14	1.17	0.89 – 1.54
spirituality	**-0.27****	0.1	0.76	0.63 – 0.92
Count model				
Intercept	-1	0.76	0.37	0.08 – 1.62
consumption	**0.4***	0.17	1.48	1.07 – 2.05
age	0.01	0.01	1.01	0.99 – 1.03
education	-0.06	0.14	0.94	0.71 – 1.25
spirituality	-0.1	0.1	0.91	0.75 – 1.10

*$p < 0.05$, **$p < 0.01$.

[a] Comparison of predicted zeros of Poisson regression 286 against the actual zeros 317 suggests zero inflation.

[b] Likelihood ratio test comparing Poisson and negative binomial hurdle models ($\chi 2$ (1) = 0.833, p = 0.361).

Nonetheless, among those who produced natural kind responses, consuming science communication increased their chances of producing yet more natural kind responses in both studies. As the results from the count model in both studies show, the intensity of the representations of awe through natural kind responses is a function of the participants' engagement with science communication. For example, one participant with a high level of consumption of science communication produced the following associates one after the other 'black hole', 'neutron star', 'uy scuti'[99], 'space', and 'universe'; natural kind responses related to space. I can safely assume that this person was simulating one situation (e.g., sitting in a planetarium, going to a science museum, watching a science documentary) where these objects are contextually correlated, meaning that the content of his representation with this emotion was mediated by his experiences in this cultural space. While trivial, these results indicate that people who participate in the culture of science communication construct richer representations of awe using natural kinds.

Such representations are tied to the cultural mandates of naturalism and environmentalism at the centre of much of this cultural space (e.g., Sideris, 2017). As experts show specialized knowledge of the domains in which they participate (e.g., Tanaka & Taylor, 1991) these results suggest that those with more exposure to science communication are more skilled at

[99] This is one of the largest known stars being more than 1,000 times bigger than the sun (S. Clark, 2019).

conceptualizing ‘awe’ using this specific type of content knowledge. I argue that this has been learned in this cultural space.

In the following two studies, I investigate this dataset further, looking for both quantitative and qualitative differences in the production norms from participants with different levels of engagement with science communication.

6.6. Study 4 - Concreteness and perceptual strength of responses

Concreteness ratings were developed in the 1960s (Paivio et al., 1968) to capture the degree to which a word refers to an object which can be perceived through the traditional exteroceptive senses (i.e., sight, sound, taste, smell, and touch). These are usually generated by group norming procedures whereby participants are asked to rate on Likert-style scales batteries of words (e.g., Brysbaert et al., 2014). These are commonly used in the grounded cognition literature where conceptual processes are understood to be partially grounded in perception (e.g., Connell & Lynott, 2012; Harpaintner et al., 2018).

Concreteness measures have also been used in studies using word association tasks. Many of these studies compare the effects of cue concreteness on response production. For example, de Groot (1989) observed how concrete cues elicited quicker association, produced more total responses, and these were more homogenous. Fewer studies, however, have looked at the concreteness of responses. Van Rensberger et al. (2015) observed a correlation between the concreteness of a word and the concreteness of the responses. Recently, Mazzuca, Majid et al. (2020) compared concreteness ratings of the responses in a free listing task between different groups of people (e.g., men/women, normative/non-normative) to the cue ‘gender’.

Concreteness measures, however, have been criticised for their lack of specificity. For example, Connell and Lynott (2012) observed how popular concreteness measures related positively to olfactory, visual, and haptic ratings, but negatively to auditory and gustatory ratings. Consequently, these authors recently compiled their own modality-specific ratings of perceptual strength for a large vocabulary of English words (Lynott et al., 2020). Their norms not only include the typical five exteroceptive modalities but also incorporate a sixth rating for an interoceptive dimension.

Considering how conceptual knowledge is in part grounded in the perceptual modalities (Barsalou, 1999), I use the available concreteness and perceptual strength ratings in the English language to compare the responses to the cue 'awe' made by those who engage and those who are disengaged from science communication. As this is only exploratory analysis, however, I did not have clear predictions about the directionality and strength of the differences in the ratings for the responses.

6.6.1. Sample

The sample from the first study (n=259) was segmented using Latent Class Analysis (LCA) into three segments – the engaged, the interested and the disengaged (appendix V). Table 6.12 shows the results of the LCA and the attitudinal and demographic differences for the three-segment solution. While age shows no difference between groups, there is a wide gender and education gap between those who are very engaged with science communication and those who do not participate in this cultural space. The engaged are mostly men and people with college degrees, while women and people without college degrees make up most of the disengaged – characteristics that other studies have documented (e.g., Runge et al., 2018; Schäfer et al., 2018). Importantly, attitudinal measures towards science were higher, as expected, for the engaged than for the other two groups.

Table 6.12

Totals, Demographic, and Attitudinal Characteristics of Three Segments of Engagement with Science Communication (n=259)

Class	Total	Tokens	Types	Age	%Female	%College degree	Trust in science[a]	Interest in science[b]	Faith in science[c]
disengaged	72	528	243	37.1	52.8	36.1	3.8	3.4	2.9
interested	127	1055	372	39.3	49.6	52	4.3	4.3	3.2
engaged	60	432	226	37.8	26.7	71.7	4.4	4.7	3.7

[a]Response to the question 'How much do you trust science in general?' (1 = not at all, 5 = a great deal)

[b]Response to the question 'How interested are you in science?' (1 = not at all, 5 = a great deal)

[c]Response to the question 'How much do you agree with the following statement? "Science can sort out any problem."' (1 = strongly disagree, 5 = strongly agree)

6.6.2. Materials

Concreteness and perceptual scores were taken from two of the most extensive norms in the English language. First, I used the Brysbaert et al. (2014) concreteness norms for 40,000 known English lemmas, which were generated in a group norming procedure from more than 4,000 participants. Second, I used the recently compiled Lancaster Sensorimotor Norms (Lynott et al., 2020) collected for six perceptual modalities and five actions. In this section, I focus on the individual mean score for both concreteness and the six perceptual modalities.

6.6.3. Procedure

After grouping the sample into three segments, all the responses produced by the participants were tokenized and lemmatized (Anandarajan et al., 2019) using the R packages 'tidytext' (Silge & Robinson, 2016) and 'textstem' (Rinker, 2018). Then I merged the tokens with their individual concreteness and perceptual modality ratings taken from the aforementioned concreteness and perceptual rating norms (Brysbaert et al., 2014; Lynott et al., 2020). Of the 2015 tokens in the sample, 52 tokens for 40 types, had no corresponding words in the norms list. This included proper nouns (e.g., 'Jordan', 'Jesus', 'Grand Canyon'), phrases ('never seen before', 'caught off guard', 'blown away', 'taken aback'), and some words that weren't in the databases (e.g., 'agape', 'ewe', 'gobsmacked'). These words were removed from the sample. I then used non-parametric analysis[100] (i.e., Kruskal Wallis) to compare the mean ranks across groups for the concreteness score and the six perceptual modality ratings (auditory, gustatory, haptic, interoceptive, olfactory, and visual) for the words produced by the three segments. This was done using the 'stats' package from R (R Core Team, 2013).

6.6.4. Results and discussion

The results of the Kruskal Wallis tests are presented in table 6.13. These show differences in the mean ranks of the haptic, interoceptive, visual, and concreteness scores of all the responses to the word 'awe' produced by at least one pair of segments. Post hoc pairwise comparisons using Wilcoxon rank sum test with Bonferroni correction were carried out for the four pairs of segments. Of particular interest were those which indicate differences between the engaged and the disengaged for interoceptive (p = 0.02) and visual scores (p = 0.006)[101].

As the boxplots in figures 6.6 and 6.7 show, the engaged produced words with lower interoceptive scores and higher visual scores than the other groups. These results are consistent with the results observed in the previous studies. People who engage the most with science communication responded with less linguistic associates. Synonyms of awe (e.g., wonder, astonishment, amazement), superordinate (e.g., feeling, emotion), and coordinate

---

[100] QQ-plot analysis showed a substantial deviation from a normal distribution for all seven datasets.
[101] Other significant pairwise comparisons include those between the interested and the engaged for haptic ratings (p = 0.02) and concreteness ratings (p=0.03).

(e.g., fear, happiness, joy) categories represent some of the most common responses. All such words related to emotion have some of the highest interoceptive scores in the Lancaster norms. The results show that people engaged with science communication produced fewer words related to emotion, as for the most part, these derive from the language system as word associations for ‘awe’. The most engaged participants rather produced words that have on average a higher rating for visual scores. This again is consistent with the previous findings in which participants with higher levels of consumption produced more natural kind responses (e.g., moon, sun, mountain, dog); words that score at the top of the visual ratings of the Lancaster norms.

Table 6.13

Kruskal Wallis Test for Scores of Concreteness and Six Perceptual Variables for Awe Norms Across Groups (N=1962)

Score	df	$\chi2$	*p*
Auditory	2	1.69	0.429
Gustatory	2	2.66	0.264
Haptic	2	8.10	**0.017***
Interoceptive	2	14.902	**<0.001****
Olfactory	2	2.99	0.224
Visual	2	9.42	**0.009****
Concreteness	2	7.48	**0.024***

$^*p < 0.05$, $^{**}p < 0.01$

Figure 6.6

Interoceptive Mean Ratings for Three Segments of Engagement with Science Communication

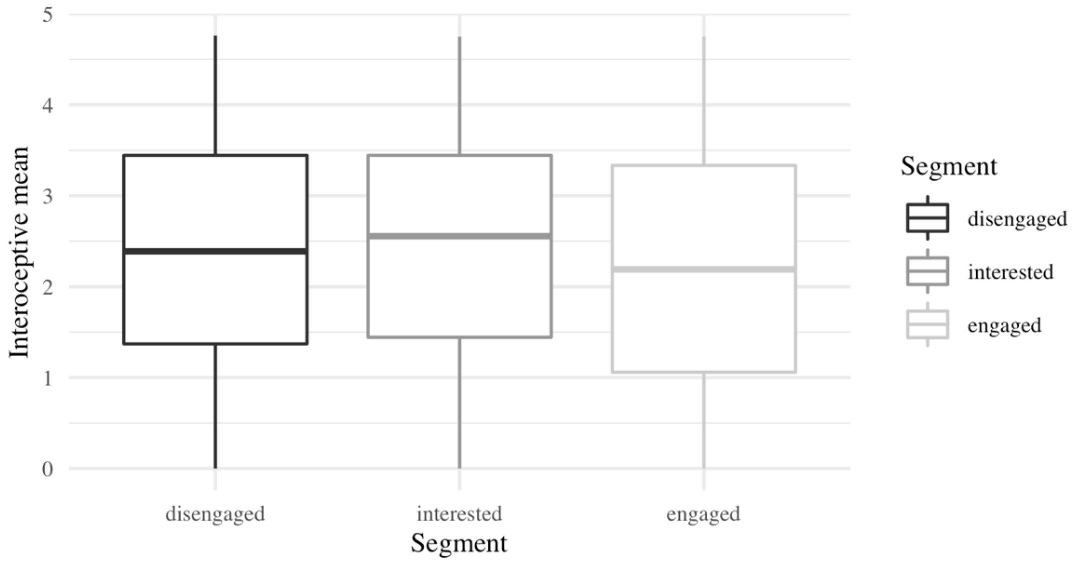
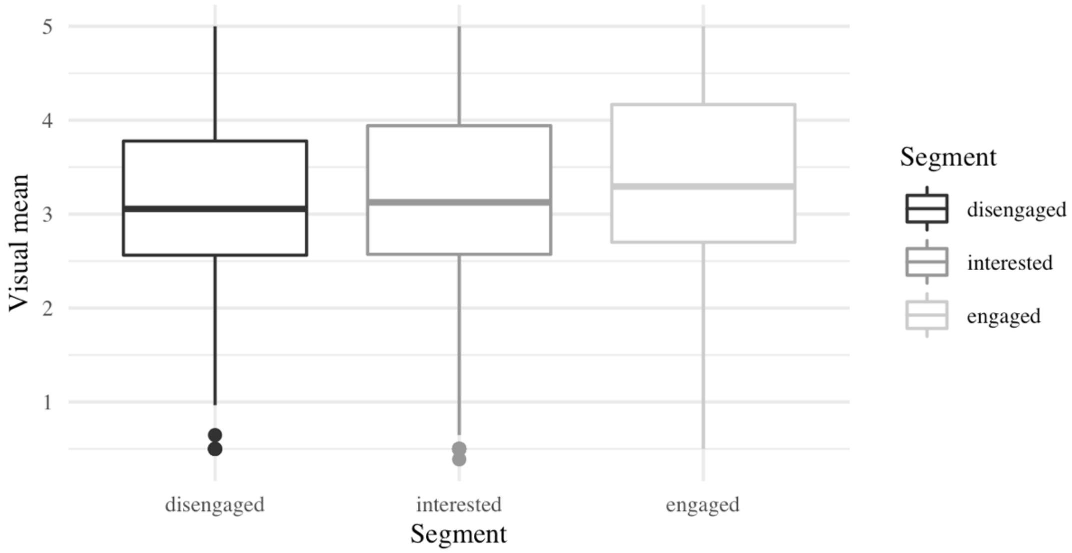


Figure 6.7

Visual Mean Ratings for Three Segments of Engagement with Science Communication



Another interpretation of these results may also involve different foci of attention in the representation of awe by people with different levels of relationship to science communication. Whereas people who aren't experts in this emotion represent the experiences interoceptively, where things like affect, arousal, and other internal sensations are at the centre of attentiveness, the emotion experience by those who engage in science communication is driven by visual cues, focusing on the shapes, contours, colours, and other visual characteristics of the objects and agents present in the awe situation. This overall suggests that people with different levels of skill have their attention in different modalities during an emotion episode. The importance of the visual system in the representation of awe suggests a potential mechanism through which affective relations with particular objects and agents related to science are established.

6.7. Study 5 - Psychological proximity analysis

One characteristic of knowledge is that it is organized in a relatively stable structure in long term memory (for reviews see Murphy, 2004; E. E. Smith & Medin, 1981). The structure of people's conceptual knowledge can be studied by looking at the order and frequency of responses in production tasks. For example, stereotypical and linguistic responses tend to be produced early during the task and cluster together, while the opposite occurs for idiosyncratic and simulated responses (e.g., De Deyne & Storms, 2008a). Measures of the psychological proximity of a response in production tasks have been developed based on their proximity to other words made by a participant and their global frequency (Crowe & Prescott, 2003). These measures can then be used to organize the relationships between responses and represent the structure of knowledge of a particular category.

Looking not only at the processing ability and content of people's mental representation of *awe* but also at the thematic structure of the knowledge surrounding this emotion category could reveal something about how other categories are related to it. More importantly, comparing the structure of knowledge of different groups could reveal other distinguishing features of people with different degrees of experience. In this last study, I cluster the measures of psychological proximity of the responses to the word association task for the word 'awe' to evaluate the structure of stereotypical knowledge for this emotion and compare its organization across groups of people with different levels of engagement with science communication.

6.7.1. Sample

The sample came from the participants from the first study (n = 259) segmented in the previous section as the disengaged (n = 72) and the engaged (n = 60) using Latent Class Analysis (LCA).[102]

6.7.2. Materials

The inter-item similarity metric was developed by Crowe and Prescott (2003) to measure the psychological distance between words in a production task. This measure is composed of two components α and $ß_w$, where α is the proximity score inside the list and $ß_w$ is a measure of its frequency across lists. The final similarity score is defined as $\alpha\beta_w$ and was calculated in R using the script from Mazzuca Majid et al. (2020).

6.7.3. Procedure

As in the previous study, the production norms were lemmatized (Anandarajan et al., 2019) using the R package 'textstem' (Rinker, 2018). Then I followed the procedure used by Mazzuca (2020) and Mazzuca, Majid et al. (2020), which was inspired by Crowe and

[102] The 'interested' were left out of the analysis as these were deemed uninteresting to the goal of comparing the structure of conceptual knowledge.

Prescott (2003), to produce word clusters for two datasets: one production norms from the disengaged and the other for the engaged. I began by calculating the inter-item similarity metric for each word in the two datasets. I then tested the clusterability of the datasets using Hopkins' statistic. A score over 0.5 suggests that the dataset can be clustered (Banerjee & Dave, 2004). After making sure the data could be grouped, I calculated four indices (C, Dunn, McClain and Silhouette) to determine the best number of clusters for each database. Finally, I employed hierarchical cluster analysis (HCA) on the data using Ward's agglomerative method (Murtagh & Legendre, 2014) results of which were visualized in dendrograms. For these procedures, I used the R packages 'factorextra' (Kassambara & Mundt, 2017), 'NBClust' (Charrad et al., 2014), and 'dendextend' (Galili, 2015) and the scripts from Mazzuca, Majid et al. (2020).

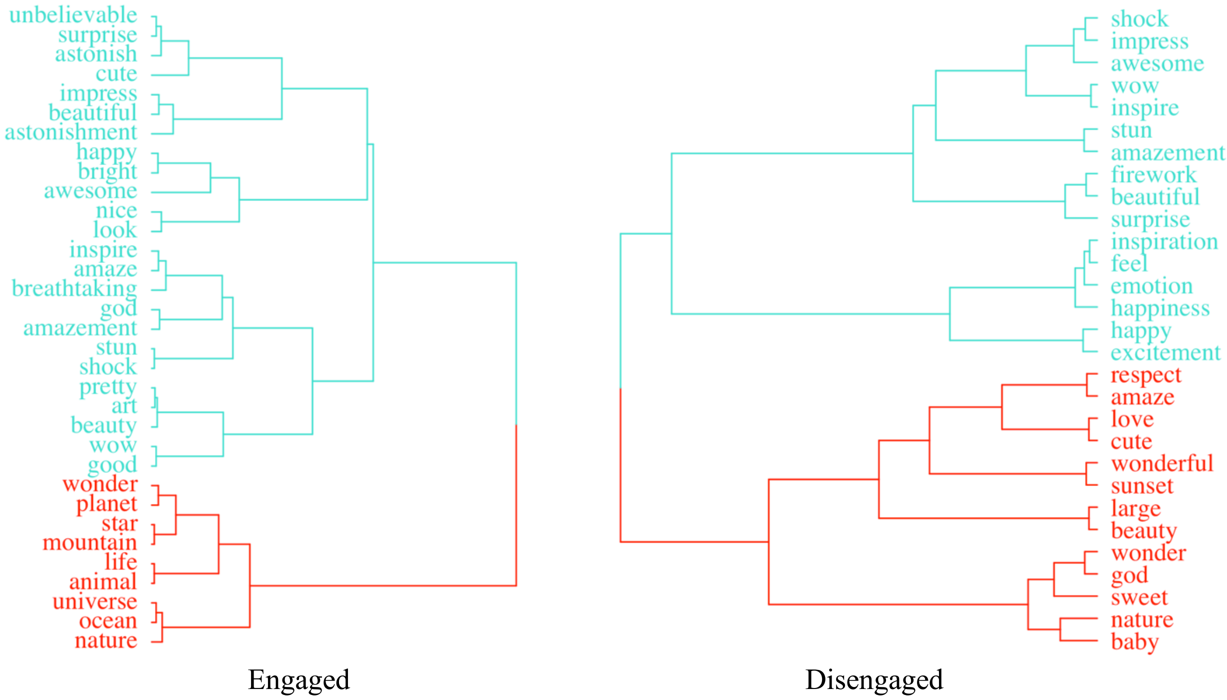
6.7.4. Results and discussion

Hopkins' statistic for the similarity ratings for the word associations produced by at least 5% of engaged and disengaged participants indicate the clusterability of both datasets (H = 0.563) and (H = 0.542) respectively. The Dunn and McClain indices for both clusters indicate a two-cluster solution while C and Silhouette suggest a six-cluster solution. I chose the two-cluster solution as it was more parsimonious. Figure 6.8 shows results in dendrograms with the clusters in different colours for both engaged and disengaged participants.

Contrasting these two visualizations qualitatively, two things are worth noting. First, the number of responses for both segments had different counts (33 words engaged, 29 words disengaged) and both lists only share 16 words in common. Most of the differences in the norms produced by the engaged and the disengaged refer to external objects. The disengaged produced five words that stand for external objects ('god', 'baby', 'nature', 'firework', and 'sunset'), categories which correspond to prototypical objects said to elicit 'awe' in a variety of different domains (e.g., religious, familial, environmental). By contrast, the engaged produced ten words that stand for external objects, most of which can be directly associated with the culture of science communication ('planet', 'star', 'mountain', 'life', 'animal', 'universe', 'ocean', 'nature'). These differences in content highlight the differences in the domains where the participants have encountered this emotion category.

Figure 6.8

Dendrograms of Word Association Norms for 'awe' from Engaged and Disengaged Participants



Most importantly, the results of the clustering indicate that the structure of knowledge of awe is different for both groups. The clusters of the disengaged don't cohere thematically. By contrast, the engaged seem to have a differentiated structure for a particular type of awe around situations connected to science communication. This is most evidenced in the second cluster (red) which includes all the external objects related to this cultural space. Importantly these words are accompanied by the most frequent word produced by all participants (i.e., 'wonder'). This organization of all the external objects around the word 'wonder' in one particular cluster shows the weight given to the knowledge related to the culture of science communication in their overall structure for the emotion category awe.

The content and structure of knowledge observed in the engaged point towards a differentiated degree of experience with this emotion (Hoemann, Nielson et al., 2020): first, they have a more differentiated knowledge structure; second, their categories are efficiently organized around a particular domain where this emotion is experienced; and third, there is a level of specific domain knowledge corresponding to the objects encountered in the culture of science communication. By contrast, the structure of the knowledge for the disengaged is rather disorganized, with stereotypical responses reflecting a degree of general knowledge received from participating in the broad culture of English speakers, but not specific to any particular subcultural space. These differences in the structure of the associations produced to the cue 'awe' support the overall thesis of this chapter, where the engaged have a higher degree of conceptual skill with this emotion category.

6.8. General discussion

Through the word association paradigm, I tested whether there are differences in the processing, content, and structure of knowledge of the emotion category awe in people with different degrees of engagement with the culture of science communication. First, I found some differences in the activation of the different representational systems. Studies 1 and 2 produced evidence that people who engage with this cultural space rely less on their linguistic system for the representation of this emotion category. I also presented some evidence in studies 3 and 5 that the engaged produce more content pertaining to the specific domain of science communication. Importantly this content (i.e., natural kind responses) is in line with the cultural mandates of naturalism and environmentalism present in this cultural space. There was some weaker evidence that higher engagement with science communication produces more responses with a higher measure for visual and less interoceptive strength (study 4). This result suggests there might be a differentiated foci of attention related to the visual system in the kind of experiences of awe that people encounter in this cultural space. Finally, in study 5, I found qualitative differences in the structure of knowledge around awe, whereby the disengaged produced broad and disorganized stereotypical responses while engaged participants organized their emotion knowledge around the domain of science communication.

Overall, these studies provide some credence to the idea that people who engage with science communication are more skilled in conceptualizing *awe*. These differences in the activation of the representational system, content knowledge, and structure indicate that people who participate through consumption activities in this cultural space may be learning increasingly sophisticated ways of conceptualizing this emotion. In going to science museums, watching science documentaries, reading about science online, and many other forms of interaction with this culture, people increasingly experience situations where this emotion category is present; acquiring the content knowledge through which they can constitute the mental representation of this emotion. With increasing skill, people rely less on a stereotypical language-driven heuristic to represent this emotion, get better at simulating it, associate it more with distinct cultural mandates, and organize its representation in relation to the domains in which it is encountered. Together, these findings suggest that people are learning knowledge of this emotion in their engagement with science communication, and they get better at its conceptualization with repeated interaction.

6.9. Limitations

The studies reported here suffer from multiple limitations. First, they do not allow for comparisons to be made between awe and other categories. Other factors that explain the differences observed might have been occluded as a result. This same design shortcoming makes it a correlational report, weakening any causal claims. The results can also be interpreted as saying that people who use their linguistic system less, or who structure their knowledge of awe better, are more interested in science. The classical views of this emotion could potentially claim this sort of directionality (e.g., Gottlieb et al., 2018). My interpretation here, however, is based on the theoretical framework to which I subscribe and the increasing evidence that supports this view (Barrett, 2017a). Future work should use strategies adhering to controlled experimental designs to test causal hypotheses that lie at the heart of this analysis.

A second issue arises as a result of the context where the task took place and the task itself. The MTurk contributors who participated in this study were all sitting in front of a screen typing words on a keyboard. Moreover, the demands of the word association task are very specific and contrived. These environmental and task constraints put a lot of limitations as to the potential to best capture differences in conceptual knowledge and skill. The situated conceptualization view assumes that concepts take functional forms related to the context and task at hand (e.g., Wilson-Mendenhall et al., 2011). More importantly, experts are better at creating mental representations that suit the functional needs of a situation (Hoemann, Nielson et al., 2020). This means that there is potentially an opposite effect of expertise in this kind of task, whereby experts would be better at simulating responses that conform to the simplicity of the task requirements and setting. It is then somewhat surprising that I found some effects in the expected direction for the differences in engagement. More importantly, this might indicate that the smallness of some of the effects observed is due to this reverse effect of expertise on conceptualization. Disentangling the sources of these effects is a task for future study designs.

A third issue arises from the sampling of the participants and controls used. While MTurk samples have shown some reliability (Buhrmester et al., 2016), there are growing concerns about the data quality produced through these platforms (e.g., Newman et al., 2021). Despite various screening criteria used the results might have been muddled by inattentive and careless responses. More importantly, the sample was taken exclusively from the United States. Generalizations to another English speaking context such as Aotearoa New Zealand should be prudent. Similarly, the study only controlled for age, education, and spirituality. A larger sample would have allowed us to control for other cultural factors such as ethnicity, religion, and socioeconomic status, which could also have some influence on how people represent 'awe'. While the results presented in this chapter suggest that the consumption of science communication influences someone's ability to conceptualize 'awe', many other cultural factors could be at play.

Importantly for the area of science communication, this study did not look at the many nuances in the conceptualization of awe considering the diversity of subcultural spaces within this domain and their many mandates. People engaged with science communication have different interests and consume different media. For example, someone interested in astronomy and museum exhibits will interact with different varieties of awe from someone who cares mostly about conservation and watches nature documentaries; spaces where they will encounter different awe types in accord with the cultural mandates within the various subdisciplines and media formats (see chapters 3 and 4). Coding the responses for specific aspects of science (e.g., astronomical objects, lab equipment, animals) or getting a more detailed sense of consumption preferences might have contributed to disentangling the diversity of people's experiences in science communication. Unfortunately, the sample sizes and questionnaires used did not allow for this level of detail.

6.10. Conclusion and future directions

Although exploratory, the results of these studies suggest that those engaged with the culture of science communication are more skilled in representing awe. Future studies can prepare other tasks and include experimental designs to confirm and improve on these findings. This future work can also take advantage of techniques such as virtual reality (Chirico et al., 2018) and experience sampling methods (Conner & Mehl, 2015) to assess the representation of emotion in a variety of settings. Additionally, future work can take advantage of the many instruments that capture people's relationship to science and science communication (e.g., Jones et al., 2020; Nadelson et al., 2014) to get a more nuanced description of the degrees and forms in which people engage with this cultural space.

Moreover, increased skill with emotion categories also brings advantages such as knowing more about the situational information that correlates with the presence of the category, constructing instantiations of this emotion that better fit the functional needs of a situation, and deliberate practice that involves novel opportunities, among other things (Hoemann, Nielson et al., 2020). Future work could also potentially test these other manifestations of increased skill of awe for the different levels of engagement with science communication. All these proposals can be done by comparing the representation of this emotion within the many subcultural spaces that exist within and outside science communication. For example, the ability to conceptualize awe can be compared for individuals who participate in other cultural domains such as tourism (e.g., Coghlan et al., 2012), religious communities (e.g., Krause & Hayward, 2015), and the world of art (e.g., Silvia et al., 2015), where this emotion is also often represented. Similarly, this kind of test could be replicated in different countries (e.g., Aotearoa New Zealand) to trial both the generalizability of the results and capture the many subcultural nuances that might arise from people having divergent experiences within these national communities. This kind of study can enrich our knowledge both about the existing types of awe and the importance of this emotion across different cultural domains. Finally, these methods could be further used to study the different emotion types and forms of expertise for other emotion categories (e.g., anger, joy, love) in people who participate in different cultural spaces (e.g., people from different nationalities, ethnic backgrounds, genders, professions, systems of beliefs). These studies could potentially enrich our understanding of emotion, moving us further away from natural kind universalist conceptions of the classical view and into the nuances of their cultural construction.

Chapter seven - How do science communicators represent awe? Qualitative analysis of interviews with science communicators

7. Introduction

University engagement officers, NGO researchers, government bureaucrats, multinational PR representatives, doctors talking to their patients, journalists writing pieces for magazines and newspapers, designers creating infographics to be displayed on billboards, enthusiasts organizing citizen science events, people retweeting scientists, and a host of different agents communicate science using a diverse set of organizational affiliations, interests, values, beliefs, and identities. Nonetheless, with the increasing professionalization of the field, the development of communities around different science communication practices, and increasing organizational commitments towards science engagement, among other developments, many have begun to organize and identify as science communicators (Baram-Tsabari & Lewenstein, 2017; Davies & Horst, 2016; F. Mellor, 2013). These science communicators have a central role in the ecosystem of the culture of science communication (Davies & Horst, 2016), producing the social representations that put into motion the circulation of shared meanings constituting this cultural space. Such representations encode a series of collective meanings that not only include the manifest, on-the-surface, patent meanings (e.g., the word ‘planet’ refers to a celestial body of a certain kind), but also the values, beliefs, norms, goals, and other forms of latent cultural expressions that lurk beneath the surface in discourses, aesthetics, narratives, and other forms of arrangements of knowledge (S. Hall et al., 2013).

Of particular importance in how science communicators produce these social representations are their histories of participation in the cultures of science communication, science education, and all other spaces where they have encountered science and its communication. While there has been little research conducted on who the science communicators are, we know that they tend to have backgrounds in science and display elevated levels of interest in the topic (e.g., Hvidtfelt Nielsen, 2010; Metcalfe & Gascoigne, 2004). Science communicators have engaged more than your average person with science and science communication throughout their lives, and hence possess enhanced cultural knowledge of this space. Such cultural knowledge can be thought of as science communication capital (see Archer et al., 2015), which is put to use in the creation of practices and products imbued with meanings from their cultural experiences as consumers of science at school, academia, and the media, among the many different spaces where they have encountered science and science communication. In short, science communicators are experts in the representation of the shared meanings that constitute the culture of science communication.

As argued throughout this thesis, the emotion category awe is valued in science communication. Little is known, however, about how science communicators contribute to the construction and circulation of the representations of this emotion through their experiences, beliefs, and practices. The present study responds to this empirical gap by investigating how a diverse group of science communicators represent awe in their lives and work, specifically by looking into how such individuals talk about this emotion.

Because research on awe has been concerned primarily with questions of universality (Cordaro et al., 2018), and has focused on a very narrow sliver of the experience of emotion such as appraisals, elicitors, and outcomes (e.g., Shiota et al., 2007; Yaden et al., 2019), most work in this area has reduced the richness of this emotion and disregarded many elements of the historical and cultural contexts where these are represented – a pattern repeated across much of emotion-based research (see Boddice, 2018, 2020a; D. M. Gross & Preston, 2020). Our very limited understanding of the contexts in which awe occurs has not given us the language to talk about the diversity of forms and functions that this emotion might have in relation to these contexts. The poverty of the descriptions of the emotional experience has also given us a stunted language that disregards the variety of settings, behaviours, and phenomenologies that accompany this emotion, and the relations of these to people's values, goals, beliefs, goals, identities, and the many other aspects of their lives in culture.

Moreover, with a few exceptions (e.g., Bonner & Friedman, 2011; Dobson, 2015), a considerable proportion of the work on awe has been done from the quantitative paradigm (e.g., A. M. Gordon et al., 2017; Piff et al., 2015). In rejecting the naïve realism of the classical view of emotions, and embracing a rather critical ontology, I believe the constructionist view of emotion (e.g., Barrett, 2017a; Wilson-Mendenhall, 2017) opens the space to new methods that go beyond the correlational (e.g., Gottlieb et al., 2018; e.g., Shiota et al., 2007) or the experimental (Danvers & Shiota, 2017; Valdesolo & Graham, 2014). Particularly, it opens the space to qualitative research that localizes ways of knowing, considers situational aspects, is aware of the researchers' own subjective and interpretative vantage point, and doesn't shy away from rich or 'thick descriptions' of the phenomena being explored (Braun & Clarke, 2013; Geertz, 1973).

Nonetheless, the constructionist view of emotions takes ontological and epistemological positions that make it incompatible with some qualitative methodologies, such as discourse analysis or grounded methods (for descriptions of these and other methods, see Braun & Clarke, 2013), which come preloaded with considerable philosophical baggage. As such, in this chapter I utilize two qualitative methods: qualitative content analysis (QCA) and reflexive thematic analysis (RTA) (Braun & Clarke, 2019; Schreier, 2012), neither of which make strong commitments to any particular view of the world and are quite flexible in accommodating diverse ontological and epistemological perspectives.

The purpose of this study is then to explore how science communicators talk about awe using two distinct qualitative methods. I conducted one-on-one semi-structured interviews with a diverse group of self-identified science communicators, where I asked them a series of questions about their experiences, overall beliefs, and uses of this emotion in their work as science communicators.

In the QCA section, I focus on the manifest content of the interviews, using for the most part top-down categories derived from the literature review in chapter two (e.g., Keltner and Haidt, 2003), the situated conceptualization analytical framework presented in chapter three (Barsalou et al., 2018) and the history of awe presented in chapter four (e.g., Burke, 1990). Whereas for the most part, this is a deductive, concept-driven approach like in quantitative content analysis, QCA opens up the codes in an inductive fashion to potential new levels within the categories (Graneheim et al., 2017; Schreier, 2012).

In the second section, I approach the data using RTA to construct larger themes that connect the ideas between the different categories in the data. Here I take a rather data-driven approach of looking at the data with 'fresh eyes' and 'detach' myself as much as possible from the knowledge that I have acquired throughout my research journey. As I recognize that there is no such thing as a purely data-driven approach and that the construction of themes is ultimately informed by my theoretical commitments, the research question, and my sociocultural reality (Braun & Clarke, 2013), RTA also assumes (although indirectly), a top-down approach.

This chapter is therefore divided into five sections. First, I present a brief methodological overview of both QCA and RTA. I then introduce the preparation stage shared by both studies. This includes a reflexive positioning of my experience in the study, the selection and sampling of participants, a description of the interview process, and the familiarization with the data through transcribing, re-listening, and copious note-taking. The third and fourth sections focus on the QCA and RTA parts of the analysis respectively. These sections include the research questions, procedures, materials, and results of the analysis. In the last section, I briefly discuss the results of the two methods, acknowledge some of the limitations of this study, and suggest some future research directions work in this area might take.

7.1. Methodological overview

The interviews were evaluated using Qualitative Content Analysis (QCA) and Reflexive Thematic Analysis (RTA). QCA and RTA are similar qualitative methods that are commonly used to analyse interview data. These two methods focus on describing social phenomena and chunking them into smaller units, whether categories or themes, for analysis (Vaismoradi & Snelgrove, 2019). There is enough overlap between these two methods in that they can be used sequentially yet are different enough to allow for distinctive levels of interpretation from the same data (Vaismoradi & Snelgrove, 2019). QCA is more suited for analysing manifest categories that lend themselves to quantitative quality checks, such as reliability controls, while RTA is better positioned for exploration, play, and creative construction of latent themes from the data in a systematic, rigorous, and thorough process (Braun & Clarke, 2019; Schreier, 2012).

QCA is a research method derived from quantitative content analysis and is used to systematically describe materials by interpreting, classifying, and reducing its parts using categories in a coding frame (Schreier, 2012). Multiple versions of qualitative content analysis exist which blur the lines with quantitate methods and thematic analysis (e.g., Elo et al., 2014; Schreier, 2012; Schreier et al., 2019; Vaismoradi & Snelgrove, 2019). Here, I highlight the distinction drawn out by Vaismoradi and Snelgrove (2019), whereby QCA is defined as a relatively simpler method, which is description-driven, drawn to categories (as opposed to themes), focused on manifest content, and open to quantification. As there is no single way of doing QCA, I use an adapted version of the most common QCA strategies (e.g., Assarroudi et al., 2018; Elo et al., 2014; Schreier, 2012), one that focuses on issues of validity and reliability, on the one hand (Schreier, 2012), and trustworthiness, on the other (Elo et al. 2014). Overall, these issues are confronted by giving detailed descriptions of the QCA process (validity, trustworthiness) and by bringing in a second coder to code and assess the main categories (reliability).

By contrast, RTA is a method used to summarize and organize qualitative data into themes[103] (Braun & Clarke, 2013, 2019). It contrasts with other forms of thematic analysis such as Codebook Thematic Analysis, and Coding Reliability Thematic Analysis, which are closer to QCA in their focus on top-down categories and coding agreement methods (Terry et al., 2017). I chose RTA as it allows me to detach myself briefly and only partially from the somewhat rigid analytical constructs that guide this research, to explore how the representation of awe is confined to larger patterns of cultural meaning.

I make a strong distinction, then, between looking for manifest categories using QCA and latent themes using RTA. This is done with the awareness of the ongoing debate in the methods community that the words 'categories' and 'themes' mean different things to different researchers, are sometimes used interchangeably, blur into one another, and that both methods can be used to discover these two forms of organizing knowledge (Graneheim et al., 2017; Schreier, 2012; Terry et al., 2017; Vaismoradi & Snelgrove, 2019). Furthermore, I acknowledge that both themes and categories can have different levels of abstraction and that these lay rather on a continuum of meaning (Graneheim et al., 2017). However, consigning the construction of manifest categories to QCA and latent themes to RTA helps heuristically to approach and scrutinize the data from distinct analytical locations (i.e., top-down/bottom-up, manifest/latent, categories/themes).

7.2. Preparation

The preparation phase for this study is shared by both QCA and RTA. This includes the reflexivity, sampling, interviewing, transcribing, and familiarization phases through which I

[103] Themes have been described as "patterns of shared meaning, united by a central concept or idea" (Braun & Clarke, 2020, p. 4), which in RTA the researcher constructs through a careful, reflexive, and organic process.

become immersed with the data. Then I proceeded independently and sequentially with the analysis, beginning with QCA, and following up with RTA.

7.2.1. Reflexivity

A central issue in qualitative research in general, and one that appears in QCA and RTA manuals, is reflexivity (Braun & Clarke, 2013, 2019; Schreier, 2012). Considering that 'I' – my sociocultural position, my idiosyncrasies, my personal history, my knowledge – am constitutive of the practices and products that make up this research, and that the communicative practices that I engage in contribute to how others construct their own realities, it is important that I recognize this subjective 'first person' point-of-view and acknowledge the ways in which it influences my research.

My relation to science communication comes from a deep affective attachment to science that began as a middle-class boy in Colombia in the eighties watching the television show *Cosmos*. Obsessed with stars, planets, and galaxies, my parents took me multiple times to the planetarium in Medellin where I accumulated the scientific, cultural, and affective capital that would later guide the many decisions I made on my way to do a PhD in science communication. It was also in those early experiences where the seed of materialism and naturalism as my core metaphysical beliefs formed. Unfortunately, the conditions both at home and in my country quickly deteriorated throughout the nineties. The war in Colombia took a precipitous turn, as drug cartels, guerrillas, paramilitary armies, and a weak state fought with great violence for legitimacy, influence, and power. The madness of the country particularly bled into my family and school where violence took the form of beatings and bullying that marked me for life. Growing up surrounded by injustices, inequality, and violence, but at the same time being fortunate enough to have had teachers, friends, the love of a mother, and a modicum of economic wealth that allowed me to get a good education, resulted in a combination of anger, anxiety, pessimism, gratefulness, charity, tolerance, sense of justice, and humanism, that has informed my life and work so far. My ontological and philosophical commitments were further refined with the discovery of Secular Buddhism as a pragmatic and ethical framework to engage with the world. In particular, its ideas of anātta and anicca, roughly translated to 'no self' and 'impermanence', respectively, have been central to my further development. It gave me the language to contest ideas about the self and identity that felt too rigid in my lived experience. Thus, although I describe myself in terms of bourgeois, cisgender, heterosexual, mestizo, bilingual, Latin American, male, able-bodied, cosmopolitan, middle-class, and have lived with the many biases, social privileges, and disadvantages that the performance of these identities have granted me, I can also describe instances in which those signifiers of identity and theories about my 'self' have been much more fluid and localized in the many situations that I have found myself in. It is in that rather more spontaneous mix and remix of cultures and experiences that acts and adapts statistically to the particular contexts that I navigate, that I encountered the theories of constructed emotions and ad hoc situated conceptualization as frameworks to evaluate social phenomena. These are theories that I believe can incorporate hard scientific descriptions of the nature of the mind into interpretivist and critical ideas in social science, and whose exponents urge people to integrate these theoretical perspectives into larger sociocultural discussions of diversity and justice. My rejection of the naïve reductionism and universalisms of the classical view of emotions is then not just tied to my evaluation of the overwhelming evidence against its tenets, but also stems from a life of experiences that have led me to conclude that one of the noblest goals in life is, as anthropologist Ruth Benedict apocryphally said about her discipline, to try to "make the world safe for human difference" (Haviland, 2005, p.133).

7.2.2. Sampling and participants

Purposive samples are common in qualitative research (Palinkas et al., 2015). I issued a call for interviewees through an advert in the PSCI-COM mailing list (appendix W) – a forum based in the UK but with more than 4,000 science communicators from around the world (JiscMail, 2020, n.d.) – to be interviewed for an hour online in exchange for the opportunity to enter a raffle for a 150EUR gift card. The original goal was to have fifteen participants, but considering the overwhelming response that the ad received, the final sample included twenty-two (n = 22) self-identified practising science communicators who used English in their daily activities. This number is above the suggested rule-of-thumb margin of 15-20 interviews for a PhD in which the qualitative section is only part of a larger project (Terry et al., 2017). After responding to the ad, participants were contacted individually via email, where they received a link to a Qualtrics (2019) form that allowed them to read the information sheet about the study and give informed consent (appendix X). They then proceeded to fill out a short demographic and professional information survey (appendix Y) concluding with a form about their preferred times on a calendar. After filling these out they received a Zoom link indicating the time for the interview.

Table 7.1

Demographic Characteristics of the Participants (n=22)

Baseline characteristic	Frequency (Percentages)
Gender	
female	11 (50.0)
male	10 (45.5)
other	1 (4.5)
First Language	
English	14 (63.6)
Other	8 (36.4)
Education	
Bachelor's degree or equivalent	1 (4.5)
Master's degree or equivalent	11 (50.0)
Doctoral or professional degree	10 (45.5)
Political Orientation	
1 - Very Liberal	4 (18.2)
2	9 (40.9)
3	6 (27.3)
4 - Centre	3 (13.6)
5	0 (0)
6	0 (0)
7 - Very Conservative	0 (0)
Religious affiliation	
Atheism	12 (54.5)
Agnosticism	3 (13.6)
Christian Catholicism	2 (9.1)
Christian Protestantism	1 (4.5)
Hinduism	1 (4.5)
Other	3 (13.6)
Baseline characteristic	Mean (SD)
Age	36.9 (9.8)

In selecting the final twenty-two participants, I took into consideration a homogeneity and a heterogeneity criterion. On the one hand, all participants had to be science communicators who used the English language at work (homogeneity criterion). On the other, I took into consideration a diversity principle that included gender, organizational affiliation, and branch of science (heterogeneity criterion). Table 7.1 presents the overall demographic characteristic of the sample while table 7.2 presents their professional characteristics. Both tables suggest a heterogeneous mix of participants in the selected criteria with participants who identified as men and women evenly represented, and participants who do a varied mix of science communication practices. There was some degree of heterogeneity as to participants place of provenance, with at least eight participants not being English primary speakers, and some diversity in their religious affiliation. There was, however, homogeneity in terms of educational background, with almost all participants having graduate degrees, and a liberal or moderate political affiliation. No participant was excluded from the sample.

Each interviewee received a number (e.g., Int1, Int2, Int3) depending on the order in which they were interviewed. I will be using these identifiers to quote them throughout this chapter.

Table 7.2
Professional Characteristics of the Participants (n=22)

Baseline characteristic	Frequency (Percentage)
Practising Scientists	
Yes	2 (9.1)
No	20 (90.9)
Organizational Affiliation*	
Freelance	5 (22.7)
University/Research Centre	10 (45.5)
Charity/Non-Profit	2 (9.1)
Science Museum/Centre	5 (22.7)
Government Organization	2 (9.1)
Science Festival and Events	2 (9.1)
Private Firm	2 (9.1)
Branch of Science	
Biological Sciences	4 (18.2)
Engineering and Technology	3 (13.6)
Physical and Chemical Sciences	5 (22.7)
Medical and Health Sciences	4 (18.2)
Environmental Sciences	1 (4.5)
Formal Sciences	2 (9.1)
Social Sciences	2 (9.1)
Other	1 (4.5)

* Various participant reported more than one organizational affiliation.

7.2.3. The interviews

All the online interviews were conducted throughout the month of June 2020 using Zoom. The interviews were video recorded using this software's recording tool. The interviews lasted on average 48 minutes with a range between 28 and 70 minutes. All interviews followed a semi-structured schedule (appendix Z) with all interviewees receiving, for the most part, the same 14 questions. The semi-structured format, however, allowed me to ask participants more questions to clarify or to expand on some things they had mentioned in one of their responses. The rationale for the interview structure was first to get participants to activate their identities as science communicators and their beliefs about emotions. Then I delved into the topic of awe by focusing on particular personal experiences with this emotion, the respondents' beliefs about it, and their use of awe in their work. This approach tapped into different aspects of their knowledge of emotion, with their beliefs being more stereotypical and their personal experiences more idiosyncratic (Robinson & Clore, 2003).[104] The interview schedule was reviewed by an expert science communicator and tested on two local science communicators whose feedback was used to improve the questionnaire.

All twenty-two interviewees were very cordial and kind in their responses and with their time. There were no major hiccups outside of standard connection problems (which were easily resolved) and several participants needing to reschedule their interview sessions. It is important to note that all participants were experiencing some degree of issues in their personal and professional lives because of the COVID-19 pandemic and the many restrictions imposed by governments in response. As a result, many of their answers were punctuated by this context.

7.2.4. Ethical considerations

Ethical issues were dealt with the utmost respect for the interviewees and the information they provided. Efforts were in place to guarantee the confidentiality, anonymity, and safeguard of their data following commonly used standards in qualitative research (Kvale & Brinkman, 2009). No serious ethical issues were raised in the processes. Following the ethics standards set by the University of Otago, I filled out an ethics committee application form Category B, which received approval on May 26, 2020, by the University's Human Ethics Committee under project number D20/151 (appendix AA).

7.2.5. Familiarization

Qualitative analysis begins with a familiarization or deep immersion into the material (Braun & Clarke, 2013). In the present case, this included transcribing, relistening to the interviews, and taking notes throughout the process.

[104] It is somewhat akin to the difference between asking a person how does a happy face look and looking at how people actually move their faces when they are happy (for a discussion, see Barrett et al., 2019).

To get closer to the material, I transcribed all interviews throughout the month of July 2020 (Braun & Clarke, 2013, 2019). From the start, I acknowledged that transcriptions are an interpretative process, in which the transcriber makes multiple decisions such as the level of detail that is included in the transcriptions and how punctuation is used throughout (Bailey, 2008; Braun & Clarke, 2013). I ignored most of the visual data, as elements of what the interviewee was wearing, the setting, or hand movement were deemed unimportant for the purpose of the research. Only when the participants made specific facial or vocal expressions related to an emotional experience and performed these as visual cues, were visual data included in the transcripts in parenthesis. Moreover, I transcribed elements of the way participants spoke following standard practices (Bailey, 2008; Braun & Clarke, 2013). Verbal tics and other fillers (e.g., 'er', 'um', 'like', etc.) and repetitions were extensively removed and corrected to maintain an appropriate flow of the text (Arksey & Knight, 1999). Besides these changes, transcriptions were kept as verbatim as possible and included some of the social chatter after the formal interview had ended, whenever this was related to the topics of emotions or awe. After transcribing the interviews (for an excerpt see appendix AB), I relistened to all of them in full at least once, both for editing purposes and for further familiarization.

I took notes during and after the interviews. I also took notes during the transcription process and after a second and third re-listen. Notes went from very broad and about the attitude of the participant (e.g., "participant seems tired", "participant's responses are very short") to the very detailed (e.g., "participant takes the rather postmodern view of facts as context-dependent and not universal or absolute"). These notes helped to organize my thoughts and alerted me of places in the interviews where there might be something of interest for later in the coding process.

7.3. Study 1 - Qualitative content analysis of interviews with science communicators

Throughout the interviews, the participants described a variety of situations in which they had personally experienced awe, believed others had experienced awe, and created contexts in which they tried to elicit this emotion in others. These situations were populated by a variety of elements which together constituted the representation of the emotion. Such elements can be disaggregated into the different categories within the situated conceptualization framework in chapter three, which include aspects such as the agents, objects, setting, events, actions, evaluations, and outcomes (Barsalou et al., 2018).

Very few qualitative studies on awe have disaggregated the situational elements present in the conceptualization of this emotion. Dobson (2015) used a method similar to qualitative content analysis[105] to describe the experiences of awe from 18 interviews. The author found a variety of elicitors, outcomes, affective states, and physical sensations which were later organized into categories such as physical, cognitive, and social elicitors, or cognitive, emotional, and physical outcomes. Similarly, Cuzzolino (2019) described a variety of elicitors, appraisals, affective responses, and outcomes of awe situations from interviews with scientists and students. These two studies observed a variety of situational elements from which they expanded on the traditional definition of this emotion.

Aligned with the main research question of this chapter (How do science communicators talk about awe?), in this section I focus my attention on the specific elements of the awe situation to arrive at the following sub-question.

Question 1: What elements of a situation do science communicators represent when they talk about awe?

With this question, I go through the interviews using QCA to look at the different aspects of the elements of the situation mentioned by the participants. The situated conceptualization view allows me to look at the content in a systematized way, separating the various elements of the awe experience within a taxonomy of situational elements.

7.3.1. Procedure

In this study, I combined elements of different procedural QCA manuals (e.g., Schreier, 2012) to develop the coding frame, review it, test it, and use it to analyse the interviews. The following were the steps carried out.

1) *Preliminary main categories*. I started with preliminary main categories using the analytical framework devised in chapter three.

[105] Although Dobson (2015) calls the approach thematic analysis it more closely resembles QCA.

2) *Segmentation*. Using a thematic criterion, I segmented the interviews into individual elements of a situation (unit of coding). This included only fragments of the interviews that alluded to the specific elements of a situation in relation to an experience, belief, or practice of awe.
3) *Pilot*. I tested the preliminary categories on two interviews. The results helped me to polish the definitions of the categories and narrow the initial categories to twelve.
4) *Coding of main categories*. I coded all the references using the codebook developed for the main categories.
5) *Reliability assessment*. I brought in a second coder to test the main categories. This person coded 20% of the segments with the main categories, with which I tested the reliability of the frame using Cohen's kappa.
6) *Simplification, abstraction, and synthesis*. The final coded references were abstracted and synthesized to generic subcategories based on similarities and on previous work on these topics to simplify the reporting of the findings. These subcategories were the result of combining a theoretically driven and bottom-up inductive approach.
7) *Reporting the results*. A large matrix was created to present the data and this section was written down.

7.3.2. Materials - The coding frame

The codebook was developed sequentially and with different iterations resulting from testing it on portions of the sample. The final categories were refined a few times to make them as clear and exclusive as possible. The results were twelve (12) main categories to code for the different elements in an emotion situation. These included:

1) *Attention foci.* The agent, object, or action that is the focus of attention during the awe situation.
2) *Social context*. Other human agents present during the awe situation.
3) *Setting*. The physical place where the awe situation occurs.
4) *Event*. Background event or actions in which the awe situation occurs.
5) *Appraisal/evaluation*. The evaluation of the agent, object, action, or situation where awe is represented.
6) *Valence*. Whether an awe situation is described as positive or negative.
7) *Arousal*. Whether an awe situation is described as exciting or calming.
8) *Other emotions*. Other emotion categories used to describe awe.

9) *Motivations*. Motivations accompanying the awe situation.
10) *Bodily sensations*. Bodily sensations used to describe awe.
11) *Action*. Behaviour or expressions performed during an awe situation.
12) *Outcomes*. Results of the awe situation.

7.3.3. Coding the main categories

It is worth pointing out some of the issues occurring during the coding process. First, each participant made references to many elements in the same category. However, there was a wide range of references made by the participants for the different elements of a situation. For example, Int11 made twenty-seven (27) references to appraisals/evaluations of an awe situation, while Int20 made only two (2). Also, while many references were manifest and had a straightforward interpretation, some of them required a degree of construal for their coding (i.e., they were more latent). This resulted in some segments being coded for multiple categories, once for its manifest content and others for more latent understanding. For example, the segment “I was just on YouTube, just watching things” (Int15) was coded as an event (online surfing), setting (in front of a screen), and social context (alone). Many of these decisions were discussed with the second coder but in the end were made based on the primary coder’s best judgement. Lastly, it is worth pointing out that some segments were discarded when the participant made the same reference to an element of an emotion situation multiple times. For example, segments in which one participant referred to feeling ‘excited’ or ‘positive’ in an awe situation more than once were discarded. Overall, the indeterminacy of language and the open-endedness of the interview format makes this kind of coding a highly subjective practice characterised by certain imprecisions. Potential objections to the interpretative nature of the coding are countered through the methodological transparency here presented, which includes the step-by-step description of the research process and clarity in my goals and limitations (Thyme et al., 2013). Most of the coding was carried out using NVivo 12 for Mac (QSR International, 1999).

7.3.4. Simplification, abstraction, and synthesis

After coding all the segments into the main categories, I simplified, synthesized, and abstracted most of the references into subcategories to streamline the results. I began by simplifying through paraphrasing and summarizing the references to more generic categories. For example, the segment in the main category “two hundred sand tiger sharks” (Int2) was simplified to the code ‘sharks’. Similarly, the segment in the appraisal/evaluation category “the contrast between white and blue” (Int11) was simplified to the code ‘contrast’. This simplification was accompanied by a process of synthesizing similar references together in one code. For example, the segments with the appraisal/evaluations “pretty”, “stunning”, and “beautiful”, were combined as the code ‘beauty’.

Considering that at the end of this process there were still too many codes for some of the main categories, I decided to create new subcategories into which I could incorporate the various codes. Here, I took both a top-down and bottom-up approach to create the subcategories to summarize the findings. For some of the main categories this was an easy process, as in the literature there is enough agreement as to what are the dimensions of this aspect of an emotion. This was the case for valence and arousal, which most literature defines as being within a continuum of positive/negative and exciting/calm, respectively (e.g., Russell & Barrett, 1999). For other categories where there is less agreement in the literature (e.g., appraisal/evaluation, motivations). Therefore, I developed my own classification scheme based on my experience, my reading of the awe literature, and my theoretical interest in science communication. This was a recursive process with no one theoretical or analytical framework guiding this level of categorization. Overall, the process of simplification, synthesis and abstraction was aimed at abridging the presentation of the results by reducing the data into a manageable number of subcategories for description. The construction of these subcategories is described in the results section.

7.3.5. Intercoder reliability

Reliability in QCA can be reached through intercoder testing of the coding frame (Schreier, 2012). I brought in a second coder to code the segmented references in the main stage of coding. The second coder was trained in an hour-long session after which they received a codebook (appendix AC) and a spreadsheet containing 220 of the 1,103 segments (20%), which is within the range of 10%~25% of the sample recommended by Krippendorff (2004). After the coding, the second coder attended a debrief session where some disagreements were discussed and resolved. Intercoder reliability showed a substantial level of agreement (Cohen’s $\kappa = 0.78$) (Landis & Koch, 1977).

7.3.6. Results

The results of the QCA can be observed in table 7.3[106]. There were 1,103 references to elements of awe situations in the 22 interviews. For nine out of the twelve elements of a situation investigated, all participants reported at least one reference. Valence, arousal, and motivations were not described by all participants. In the next sections, I describe the findings for each of the main categories.

Table 7.3
Results from QCA

Name	Quote	Interviewees	References	Examples
1. Attention foci		22	182	
Accomplishment	"I hear their cancer story and hear that they are now doing really well or they achieved something amazing" (Int 7)	6	9	a child learning quickly, an Olympic accomplishment
Living organism	"We were snorkelling at the time and we came across a school of squid, and it was just like insane" (Int 15)	14	23	a school of squid., mosquito larvae, sharks
Natural object	"I was amazed by the grandeur of the planet." (Int 16)	17	48	blackholes, sunsets
Non-science related artefact, practice, or idea	"The building itself inspires awe" (Int 9)	15	31	a book, musical instruments, philosophy
Non-science related person	"People with marginalized identities that advocate bravely and proudly for themselves against all adversity. I feel like they are doing something important, so I feel in awe of them." (Int 22)	3	4	acrobats, community workers, marginalized people
Science-related artefact, practice, or idea	"the CERN particle accelerator and stuff (.) well they fill me with awe" (Int 3)	20	61	a new technology, robots, the Galileo project
Science-related person	"I was almost in awe of my doctors" (Int 7)	4	6	doctors, science communicators, themselves
2. Social context		22	32	
Alone	"I read it over the internet" (Int 20)	9	10	
Dyad	"And it was, you know, pitch black, dead of night, strong wind and just the two of us there" (Int 5)	6	8	with one friend, one-on-one
Small Group	"there were a couple of friends over" (Int 13)	8	9	close family, in a team
Large Group	"everybody was really worked up at that point because they wanted to see" (Int 6)	4	5	as member of an audience, in a class
3. Setting		22	75	
Natural	"have these little moments of wonder in the everyday nature" (Int 4)	11	16	a cave, beach, desert
Non-science-related built	"in our room where we had all been living for the last few weeks on top of each other" (Int 1)	22	42	auditorium, bar, theatre
Science related built	"it would ruin the awe of the experience of walking into the aquarium the first time" (Int 2)	14	17	aquarium, natural history museum, observatory
4. Event		22	71	
Arts, culture, and entertainment	"I was there at a museum" (Int 18)	11	19	at an arts festival, watching a film

[106] A complete list of situational elements mentioned by the interviewees can be found in appendix AG.

Business and trade	"I have a mentoring role" (Int 12)	6	8	mentoring, researching
Private	"I was driving home" (Int 12)	9	10	driving, talking with a doctor,
Scientific and educational	"I was conducting a workshop and it was about robots" (Int 13)	15	22	doing astrophotography, science conference,
Sports and recreation	"we'd had a couple of beers and we were just chatting" (Int 9)	10	12	diving, going for a run, on a walk
5. Appraisal - Evaluation		22	309	
Aesthetic of merit	"There are so many different people who have such different academic qualifications, such different professional backgrounds that come together to do science communication, that is something that is really impressive" (Int 14)	12	22	ability, diversity, importance, virtue
Aesthetic of the Burkean sublime	"If as if I could physically experience the empty separation between myself and the sun. And it was immense. And it was immense in a way that I couldn't comprehend but I could feel" (Int 11)	19	83	complexity, confusion, rarity, vastness
Aesthetic of the marvellous	"I think it is just so, crazy to even just think about them, and I mean, they can be very kind of stimulating in a sensory way, like the images of the cosmos are. Insane!" (Int 15)	22	102	anticipation, catchiness, coolness, unexpectedness, uniqueness, weirdness
Aesthetic of beauty	"it was like these very small scale, hands on, tactile things, but they were very much focused on getting people to observe and notice things that they may have not noticed before" (Int 1)	17	44	beauty, caring, cuteness, familiarity, fragility, silence, simplicity, smallness, stillness
Aesthetic of the supernatural	"there is something transcendental about it I suppose, (.) and (..) it is probably the nearest thing I guess that non-religious people get to something akin to the feeling that people have in (.) sort of ecstatic religious experiences" (Int 3)	15	46	connectedness, ignorance, immersion, incomprehensible, ineffability, numinous, transcendental
Other aesthetics	"I thought it was a really cool way of making something really funny, really memorable" (Int 17)	8	12	animated, funny, futuristic, identification, participation
6. Valence		16	16	
Positive	"I think it's a positive emotion" (Int 20)	10	10	
Positive and negative	"it could be a negative thing." (Int 2)	6	6	
7. Arousal		14	15	
Both exciting and calm	"it's exciting, but there is also a kind of peacefulness" (Int 2)	2	3	
Calm	"So I just felt peaceful, very relaxed" (Int 8)	2	2	
Excited	"I was very excited." (Int 19)	10	10	
8. Other emotions		22	113	
Stereotypically described negative emotions	"I think there are ways in which awe can be sad" (Int 5)	6	7	disgust, fear, jealousy, loneliness, sadness
Stereotypically described positive emotions	"I think it's a positive emotion so I don't know if I would go so far to say happiness, but (..) it is a sort of a joyful feeling. Maybe some aspect of joy (…). Happiness" (Int 21)	22	106	amazement, ecstasy, empathy, gratitude, happiness, inspiration, joy, love, pride, wonder
9. Motivation		17	58	
to act	"maybe also feeling the power of optimism (…) like we can do a lot " (Int 18)	4	6	

to create	"it makes me want to create something myself" (Int 18)	2	2	
to explore	"I kind of wanted to engage with it in more depth somehow, yet at the same time knowing that it probably was impossible" (Int 3)	1	2	
to learn	"it is like motivating, in a way. To be able to find something new" (Int 10)	11	32	
to share	"I wanted to tell people about it" (Int 10)	6	8	
to stay in the moment	"I wanted to stay within that moment" (Int 3)	2	3	
to transcend	"this strong push I feel inside me to be one" (Int 22)	1	1	
to work	"encourages you to keep doing what you do" (Int 14)	2	4	
10. Actions		20	70	
Behaviour	"frozen quite still for a moment." (Int 2)	13	21	clapping, engage with the object, freezing, grab nose, move away from object
Communicated to others	"I shouted. (laughs) “It is happening”" (Int 1)	7	9	communicate online, verbal communication
Expression	"when you can see someone else’s eyes go wide" (Int 9)	18	40	crying, saying 'wow', smiling
11. Bodily sensations		18	56	
Full body sensations	"I shiver, I got a little bit of a shiver" (Int 5)	16	31	buzz, dizziness, lightness
Localized sensations	"I couldn’t breathe. The thing is you can't breathe when you are watching it" (Int 11)	8	11	choking, different heartbeat, heavy breathing
Mental sensations	"and very present in the moment of (.) kind of watching this unfold for me it’s watching, watching this experience unfold and (.) seeing how(.) I think there is also this intense focus" (Int 21)	7	14	autopilot, euphoria, focus, out of body experience
12. Outcomes		22	106	
General outcomes	"It might not be in a lab. It might not be an academic setting, but it feels as though you have achieved something really great." (Int 14)	20	63	assign value to a person, constitute a memory, realization
Science-related outcomes	"I mean the absolute ideal the one that I aim for and don’t always achieve is wonder, when people eyes go (open eyes) 'waaa' and even if they are not saying, in their head, you know that they are going 'oh my god that is so cool', because again, that’s building that relationship with science." (Int 9)	19	43	build a relationship with science, connect science with daily lives, create an expectation about a technology, learn science, loose trust in science
Total		22	1103	

1) Attention foci

All participants referred to at least one agent, object, or action that was the focus of attention during the awe situation. The resulting 182 references (*M* = 8.27; SD = 3.25) were subdivided into seven subcategories. Considering the topic of science communication framed the interviews, it is not surprising that the most common representations were of scientific artefacts, practice, or ideas. This category included various technologies and scientific theories (e.g., nanotechnology, robots, and the theory of evolution). Other participants alluded to detailed instances in science communication such as "getting the right metaphor, for example, heavier than this many elephants" (Int3), or a specific science demonstration with "liquid nitrogen or fake blood" (Int17), that incited awe in an audience.

This category is followed by the most commonly cited source of awe: natural objects (Shiota et al., 2007; Yaden et al., 2019). This includes mostly large objects such as mountains, the Grand Canyon, and the whole planet. This, contrasted with the category living organisms, many of which were small such as flowers, moss, courgettes, birds of paradise, and a fox. A variety of non-scientific positive and negative artefacts or ideas were also named as appearing in awe situations, including the New York cityscape, God, and rioting. The last three categories were accomplishments (e.g., Olympic achievements), non-science-related people (e.g., community workers), and science-related people (e.g., a science communicator). There was an incredible variety of objects large and small, scientific, and non-scientific, common and rare, that were described as awe-inspiring, and these were represented across the board by all participants.

2) Setting

Participants describe a multiplicity of natural and built settings where awe is experienced by them and others. The most common overall place where people reported experiencing awe was in front of a screen (11 participants). In settings related to science, participants described awe while at science centres (5 participants) and museums (5 participants) as places where people experience awe the most. This might be related to the fact that most of the participants work or have worked in some capacity in projects related to such institutions. Aquariums, science festival stands, and natural history museums were also locations where participants reported experiencing or seeing others experience awe.

3) Event

The typology for events was adapted from the tourism literature (Getz, 2008) to include five subcategories. Again, interviewees reported experiencing awe during all sorts of activities that included sports and recreation (e.g., while running, while snorkelling), private activities (e.g., driving home, having beers with friends), and activities related to arts, culture, and entertainment (e.g., watching a film). In relation to scientific and educational events, the most common occurrences of awe were during science shows and demonstrations, on the one hand, and during visits to science centres, museums, and aquariums, on the other.

4) Appraisals/Evaluations

While the literature on awe traditionally focuses on two (or seven) appraisals (Keltner & Haidt, 2003) people use all sorts of adjectives, adverbs, and other modifiers to describe the objects that induce awe. Here, I constructed sixty-two (62) different categories to organize the many appraisals and evaluations made by the participants of the situations where they or others experienced awe. I further organized these around five "aesthetics" corresponding to some of the discourses described in chapter four. The aesthetic of the Burkean sublime takes from Burke's list of elements that make something sublime (Burke, 1990), while the aesthetic of merit is similar to the themes of admiration and virtue described by contemporary researchers (e.g., Keltner & Haidt, 2003). Similarly, the aesthetic of beauty was constructed around the themes of the wondrous and the beautiful (e.g., Economides, 2016; Moore, 2005), and the aesthetic of the marvellous around the discourses of wonder related to the marvels of the Wunderkammer (e.g., Daston & Park, 1998). Finally, the subcategory of the supernatural was related to some of the religious and spiritual themes around awe described in previous chapters (e.g., Otto, 1923; Van Cappellen & Saroglou, 2012).

The most common overall appraisals were vastness (14 participants), coolness (12 participants), ability (11 participants), novelty (11 participants) beauty (11 participants), incredibleness (10 participants), and connectedness (9 participants). While these match some of the stereotypical appraisals described in the literature for awe (Yaden et al., 2019), others do not. Moreover, not all participants expressed such stereotypical evaluations. Many expressed appraisals that do not appear anywhere in the literature on awe. These include fragility, funniness, futuristic-ness, diversity, and cuteness. Some of these 'atypical' appraisals didn't fit the mould of the five subcategories created and therefore were coded as being in the 'other appraisals' category.

5) Valence and Arousal

Many participants described awe situations as positive (10 participants). However, some of them (6 participants) acknowledged the possibility of awe being a negative emotion. For example, Int22 mentioned how "sometimes awe can be also something really terrible", while

Int12 described that this emotion “gives you some pleasure and some pain at the same time”. Similarly, while most participants spoke about excitement as a component of the awe situation (10 participants), two participants described situations of awe as calming, and two others described these as both. Int8 described awe as making them “very relaxed”, while Int2 described it as “it’s exciting, but there is also a kind of peacefulness”. The ambivalent nature of the valence and arousal descriptions of awe is what has led some researchers to label it as a complex emotion (A. M. Gordon et al., 2017; Shiota et al., 2011).

6) Other emotions

The participants used various other emotion categories to describe their experiences with awe. Emotion categories stereotypically described as positive such as joy (6 participants), happiness (12 participants), surprise (12 participants), inspiration (7 participants), amazement (7 participants), and wonder (8 participants), were the most used by participants. Other positive emotions words such as love, empathy, trust, and contentment also accompanied such descriptions. The most common negative emotion was fear, described by three participants. Other emotions with negative connotations such as sadness, loneliness, disgust, and jealousy were also concurrently used to describe awe situations.

7) Motivations

Most interviewees described people, including themselves, as feeling an urge to do something accompanying awe situations. Various participants (11) described some version of wanting to “seek out more information” (Int1), wanting “to know more” (Int18), or becoming “hungry for the answer” (Int22). Six more participants used the category curiosity in relation to an awe episode. This motif of wanting to learn more fits with the ‘need for accommodation’ premise that accompanies many descriptions of awe in the literature (Keltner & Haidt, 2003). However, other motivations such as wanting “to tell other people” (Int7), “to create something” (Int18), and “to stay within that moment” (Int3) were also described. Besides the work that has argued for the information-seeking potential for awe as a so-called ‘epistemic emotion’ (Valdesolo et al., 2017), the motivational elements that attend an awe experience have been widely ignored in contemporary work on the subject.

8) Bodily sensations

Bodily sensations are part of the affective component of the situated conceptualizations framework. I divided these bodily sensations into three categories in relation to whether these referred to the full-body, localized in a particular place in the body, or whether there was some reference to a mental construct or state of mind. Although these are all leaky categories, with no clear definitions in the literature, they served as effective heuristics that enabled me to simplify classification. The interviewees used words such as overwhelm (5 participants), lightness (4 participants), shock (4 participants), smallness (3 participants), and shivering (2 participants), to describe how their bodies felt during the awe situations. Of these, only smallness and shivering appear in the literature of awe as constructs (e.g., Piff et al., 2015; Schurtz et al., 2012). Localized sensations such as feeling choked (2 participants), different heartbeat (2 participants), and heavy breathing (2 participants) were also mentioned by the interviewees. Complex mental constructs such as euphoria (2 participants), focus (3 participants), and being mind-blown (4 participants) refer to conceptualizations that are heavily in the body yet also reflect states of mind. The description and exploration of many of these motifs requires further investigation.

9) Actions

I divided the descriptions of actions during awe situations into three categories: behaviours focusing on the body, expressions on the face, and communications with the use of spoken and written words. I recognize that these categories are somewhat arbitrary, as all actions communicate something (Mehrabian, 1970) and that the separation of expressions between the face and body is rather tenuous (Van den Stock et al., 2007).

Expressions that are stereotypically associated with the emotion 'awe' (Cordaro et al., 2016; Shiota et al., 2003) such as the expression 'wow' (12 participants), wide eyes (2 participants), deep inhalations (2 participants), and open mouth (1 participant) were brought up by some of the interviewees. However, they described many other actions, such as smiling (4 participants), crying (2 participants), reaching out online (2 participants), saying something to someone (6 participants), and clapping (1 participant). These are only but a small subsample of the potential diversity of actions that people do when in awe. Also, while some describe engaging or approaching behaviour, some participants described freezing or staying in place (Int2), while one participant described how some people could potentially "disengage entirely" (Int9) during an awe episode as a result of it being "too crazy" (Int9) for them. Again, this goes to show that while stereotypical expressions and behaviours exist, a potentially unlimited range of actions can accompany an awe situation.

10) Outcomes

In the category outcomes, I returned to organizing situations as to whether they were in the context of science communication or not. This proved difficult, as some referred to general outcomes that could occur within this context, but at the moment when the interviewee was describing this, they were not making exact reference to a science communication situation. For example, various participants talked about caring about something (4 participants) as a result of an awe experience. In some cases, they were referring to nature - "to appreciate what that ecology is" (Int1), – or more broadly about the idea that awe can get people to "care about something" (Int3). Similarly, a few participants described realizations as a common outcome from an awe experience. Participants described realizing how lucky they were, or how they gained new insight, as a result of an experience with awe. They also reported receiving a reward (6 participants) or a sort of reinforcement (4 participants). While not necessarily directed towards science, these general outcomes could potentially be tied to this subject.

When it comes to outcomes strictly related to science and science communication, the most common responses described by the participants were learning some new science (8 participants), capturing someone's attention with science (6 participants), building a relationship with science (5 participants), and influencing people's career paths (4 participants). Not all these outcomes were positive, as some reported things like preventing children from learning, making people lose trust in science, making science less accessible, and making people fatigued about science. The implications of these results will be discussed in the next section.

7.3.7. Discussion

Three overall conclusions can be described from the QCA regarding how science communicators represent awe. First, the overall stereotypical features of awe presented in the literature as an emotion caused by objects in nature described as vast, that generate arousal and positive feelings, and that result in some form of learning (e.g., Keltner & Haidt, 2003;

Valdesolo et al., 2017), are somewhat frequent in science communication. At least half of the participants described elements of awe using this ordinary cultural type. Importantly, some of these representations also included the negative stereotypical connotation. From objects stereotypically described as negative causing people to experience awe, to descriptions of negative affect and emotions, various participants expressed in different forms situations that were of an undesirable kind, some of which were connected to the communication of science. These are in line with descriptions of a negative variant of awe in the literature (e.g., A. M. Gordon et al., 2017)

However, participants' descriptions using these frequent stereotypes were also accompanied by a wide-ranging variety of other elements. The second conclusion of this QCA is that there is a wide range of elements of experience that do not conform to the stereotypical features of awe described in most of the literature. From descriptions of awe as fragile or funny, to associations with disgust and love, variability of awe experiences was the norm (see Barrett, 2017a).

Many of these representations, however, weren't random. There were common patterns in the participants' descriptions of awe in relation to science communication. For example, science museums and science centres were identified by multiple interviewees (10 participants) as a place where awe is experienced. Similarly, half of the sample (11 participants) associated awe with a motivation to learn or curiosity. Importantly, several participants consistently mentioned certain goals for this emotion such as capturing attention (6 participants) and building a relationship with science (5 participants) indicating the functional similarity of many of its uses in this cultural space. The consistency in participants' responses around certain forms and outcomes of awe is derived from the many cultural themes or scripts[107] for this emotion that circulate in science communication and beyond this cultural space. The participants integrate the elements of a situation into a cohesive framework using these scripts giving coherence and social meaning to their awe beliefs, experiences, and practices.

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[107] These are a form of larger patterns of social meanings which could also be described as narratives, schemas, frames, discourses, or themes (see next section). I use here the term script as it is referenced by Boddice (2019, p. 50) who quotes the following passage by historian Robert A. Kaster (2005, p. 8) "emotion properly understood…is the whole process and all of its constituent elements, the little narrative or dramatic scripts that is acted out from the evaluative perception at its beginning to the various possible responses at the end. Subtract any elements of the scripts, and the experience is fundamentally altered, without a response". Boddice (2019) then goes on support this view of emotions as scripts though he cautions against the literal understanding of scripts as screenplays, but rather highlights their unconscious and dynamic aspect.

It is through these practices where these scripts are constructed and reproduced in the culture of science communication.

More important, these scripts are co-constitutive of the various and sometimes conflicting mandates that circulate within science communication. Many seem to include elements that give awe a positive connotation while supporting many of the goals implicit in deficit-style norms of science communication including promoting science careers, teaching science outside the classroom, and ensuring public support for scientific activities (e.g., Metcalfe, 2019; Stocklmayer, 2012). Nonetheless, some of the forms and outcomes described by the participants deviate from these norms and their accompanying beliefs, identities, and worldviews. For example, descriptions of awe that 'makes people distrust science' or 'prevent people from learning' suggest the presence of divergent cultural scripts around awe based on contrasting mandates. However, the disaggregation of the awe situation into its constitutive elements performed in this QCA doesn't permit further elaboration into the nature of these larger patterns of meaning. To understand the frameworks that tie together the elements of the awe situation in the culture of science communication and relate these to the various mandates in this space, I now turn to the second study of this chapter, in which I use RTA on the same dataset and construct themes that thread these elements together.

7.4. Study 2 - Reflexive thematic analysis of interviews with science communicators

As participants answer questions about their personal experiences with awe, their beliefs about this emotion, and their practices around these, they are not only activating, partially simulating, and communicating their conceptual knowledge of this emotion category through its individual elements, but they are also tying these together in larger and underlying patterns of social meaning. These could be described as cultural scripts, motifs, discourses, narratives or, for the purpose of this study, themes. These themes give structure to the elements of an emotion situation described in the previous study and organize how people construct the representation of an emotion within a cultural context.

Importantly, the different themes through which people represent awe in science communication are deeply entwined with the various cultural mandates in this space. By contrast to QCA's focus on more manifest content, RTA allows the deeper latent work required to describe the presence of these cultural mandates and the work they perform in the construction of the studied emotion category. Moreover, this type of interpretative exercise acknowledges the two-way constitutive manner through which the emotion type is not only a function of the mandates but through which these mandates are imbued with affective content. Themes then, serve as an overarching framework of meanings within which people's beliefs, values, norms, goals, and identities are tethered, co-constructing affect and emotions on the one hand, and the rest of the elements of experience on the other.

Previous qualitative work has tried to look for larger themes of awe within the narratives presented in interviews. Bonner and Friedman (2011) discovered some 10 themes around different appraisals for the awe experience. However, the source of their material has been criticized by other studies (e.g., Dobson, 2015). Dobson (2015) identified some themes such as detached observation, active re-evaluation, and sense of connection. Hicks and Stewart (2020) described the different meaning-making and learning outcomes from awe experiences involving wildlife. In a similar vein, Cuzzolino (2019) identified three major themes around awe in the way scientists talk about their experiences with this emotion, including: 1) its relationship with the process of discovery; 2) awe as positioned to prior experience; 3) and awe as highly variable and elusive. These studies have contributed by giving more nuance and richness to our understanding of this emotion in different contexts (e.g., wildlife experiences, scientific culture, etc.).

In this section, I explore some of the larger patterns of meaning through which science communicators construct their beliefs, experiences, and practices of awe, and ascertain how these constitute the culture of science communication. Therefore, the research question guiding this investigation can be stated as follows:

Question 2: What are the themes around which science communicators construct their representations of awe?

Uncovering those patterns of meaning can help us understand not only the structures that hold together the different forms of representation of this emotion in this cultural space but also uncover some of the mandates at the core of our science communication practices around awe.

7.4.1. Procedure

After having completed the QCA, I re-read the interviews, engaging in a systematic coding of the data focused on identifying the larger patterns of meaning in relation to the research question. In this stage, I coded 407 passages with very broad paraphrasing to capture both their manifest and latent content (phase 2). I then proceeded to construct narrower themes around certain cultural mandates underpinning the representation of awe within this cultural space (phase 3). Here I used my interpretive abilities to look beyond what was being stated by the practitioners, taking their representations as situated, partial, and combinatory reconstructions of a lifetime of experiences steeped in multiple cultures with contrasting and sometimes contradicting types of this emotion. I then reviewed the themes multiple times (phase 4) and polished their names (phase 5). Throughout these sections, I was aided by NVivo 12 for Mac (QSR International, 1999). Finally, I wrote the results and discussion sections (phase 6).

7.4.2. Results

My interpretation of the data is closely tied to my reading of the history of awe and understanding of science communication presented in chapters two, three, and four of this thesis, whereby I described the varieties of awe and subcultures of science communication as organized around differing, and sometimes conflicting, values, beliefs, norms, and goals (i.e., cultural mandates). While individual science communicators showed a preference for one or two themes, for the most part, their answers showed a mixture of many influences. Some respondents were even aware of the tensions between mandates and were critical of certain types of awe and/or of the emotion category awe altogether. I composed six main themes (entertainment, curiosity, admiration, revelation, connection, humility), each with a central organizing sociocultural function that threaded together the different forms this emotion took and the cultural mandates it co-constructed. A variety of representations that did not fit any of the main themes were put in a seventh theme (other). Lastly, I created an eighth theme (diversity) around the critical voices of this emotion who advocated bringing an increasing diversity of emotions into the culture of science communication.

1) *“you have your audience for a small time, and you need to try to hook their brains”* **(theme - entertainment)**

One of the most common images of awe in science communication was that of the science communicator, usually a science demonstrator at a museum, using a big explosion to grab the attention of a crowd:

“so, people go for those big bangs, those big kind of ‘here is a demo (rocket sounds)’ like trying to make some kind of emotion, which is like the kind of ‘wow’, wonder” (Int3)

These flashy and electrifying hooks often come with the presentation of a novel or unique object and are used at the beginning of a communication event to shock and marvel the audience, tickling their “interest” (Int20) and creating an “excitement about science” (Int19). Besides explosions and experiments at science demonstrations, there are a host of techniques used by science communicators to create these forms of marvellous awe. These include journalists appealing to “clickbait” (Int13), documentary filmmakers using images of pristine nature (Int1), writers creating lists of extraordinary facts (Int2), and the general use of enthusiasm in science presentations (Int17), all of which aim at entertaining the audience and gaining their attention (Davies, 2021; Jeffries, 2003). One interviewee described these practices as being on one end of a spectrum:

“on one hand you’ve got, the science communicator who is the container of all knowledge (.) trickling information down in a very sterile and cold way (.) and on the other end of the spectrum, you’ve got science communication done just for fun, just for its entertainment value. And you’ve got emotions in both areas. On the first hand is probably going to be boredom and the other one is probably going to be just (.) surprise, just awe, just wonder.” (Int6)

This version of awe-as-entertainment is tied to its long history of popular objects of marvel from the European *Wunderkammers* (“cabinets of curiosities”), to the Barnum-type circus acts, magic shows, and contemporary forms of public spectacle, this emotion has long been used for entertainment (Daston & Park, 1998). Rather than a private matter, this type of awe is to be experienced and expressed collectively, openly, commonly, and loudly (Nye, 1994). However, in the same way that the interviewee is dismissive of this type of awe as ‘done just for fun', several popular forms of this emotion have been historically looked down upon as inauthentic and 'vulgar' (Daston & Park, 1998; Nye, 1994); this judgmental, sometimes elitist, attitude pervades much academic work in this area and dismisses certain experiences as not being "true" awe (e.g., Keltner & Haidt, 2003).

Other interviewees voiced parallel concerns about this type of awe-as-entertainment. They argued that these kinds of showy displays were being "overused" (Int11), that they were used in a "lazy way" (Int13), and that they made people fatigued (Int9). Another critique was the charge that this kind of awe can prevent people from learning, as the participants are too transfixed by the excitement brought about by the 'awesome' object, and that as a result they would be distracted away from the actual scientific information being conveyed (Int2).

Despite the many criticisms, this form of awe was utilized by many of the interviewees. Some interviewees acknowledged that, as the result of the competitive pressures from the attention economy in the broader capitalist consumerist society (see Crogan & Kinsley, 2012), where everything "is very flashy" (Int6), it becomes increasingly hard to get people to pay attention to science. As a result, this ends up becoming the default form of science communication. As one participant put it:

"As science communicator, you have your audience for a small time and you need to try to hook their brains, you need to find a hook somewhere. So, going for that sense of awe I think is a very traditional thing to do in science communication." (Int4)

More importantly, some also saw the possibility that this could lead to science being oversold, and people losing trust in science when it did not deliver (Int13). Perrault (2013) argued something similar about certain kind of science popularisers who use things like wonder to hype science. While hype can be used as a positive practice in certain circumstances (Roberson, 2020) many science communicators seem to find themselves walking a tightrope between their beliefs about hype on the one hand, and the increasing demands from an unrelentless competition for 'eyeballs', on the other.

2) *“curiosity is the thing that kind of draws you down the path and the buzz you get is for fulfilling that curiosity”* **(theme - curiosity)**

Curiosity has established itself as a cardinal value in many science discourses (Ball, 2013; Daston & Park, 1998; Harrison, 2001) and as something to be promoted in science communication activities (e.g., Davies, 2019; Onion, 2016). Motivated to know more, the scientifically minded individual investigates, probes, examines, and tests, dedicating time and energy towards satiating that curiosity. At the end of this curiosity-driven journey is an intense emotional response described as ‘awesome’. The reward is so powerful that the individual seeks more, entering a feedback loop of curiosity and awe, which one participant described as an addiction.

“You know, I would say it’s enticing. It’s a rush. It’s a weird mixture between satisfying but also unsatisfying because it entices you to more (.) it’s almost like an addiction (...) Addiction sounds bad, but I think it shares a lot of things with addiction in the way that is both satisfying because it feels so nice, but it is also, you need more, that’s why I keep doing it” (Int9).

By contrast to the previous version of awe which usually came at the beginning of the science communication event, this version of awe requires a build-up, through a narrative (Int9), a long and measured activity (Int1), creating a safe space for an audience (Int13), or any other strategy that requires exploration and discovery and that takes time to build up into a climactic emotional experience. This conception of the slow-burning and curiosity-driven science communication event mirrors ideas about the research journey and wonder of discovery at the centre of much of the scientific ethos (see for example, Dawkins, 1998; Henderson, 2017). Awe is thus described as an affective prize for hard work, discipline, and patience.

Whereas the use of awe as entertainment was sneered by several respondents and seen as an inauthentic, gimmicky, or lazy practice, its association with curiosity was, for many science communicators, seen as virtuous and central to their identity within this cultural space. The interviewees mentioned how awe motivates the public to “go home and talk about what they saw” (Int17), getting them to want to “find out more” (Int10), “inspiring them” (Int7) to “reading new stuff or meeting new people or travelling to other places” (Int12); practices and processes that build a "relationship with science" (and science communication) (Int9). Analogously, some participants recognized these experiences of awe as a professional motivation to work as science communicators, where their biggest reward at work was to "infect someone else with awe" (Int9). Some practitioners even saw themselves as experts in this emotion.

"I think that I experience [awe] probably, at a higher frequency to most people […] I think that it is because I tend to be quite kind of open to new experiences and to (.) if I experience something, I try to experience it fully. Whereas some people you know, will only initially engage partly with something and they have to be brought out of their shell." (Int9)

"conveying a feeling of awe is only possible if you have it in the first place (.) so if I didn't feel it every day, I wouldn't be able to convey it in the same way that I do (.) because it wouldn't be authentic" (Int22)

When describing awe and its role in inspiring curiosity, values such as openness to experience, the ability to be present in the moment, sharing, and authenticity, featured prominently. For some respondents, Carl Sagan was the paragon of science communication, not only because of his scientific knowledge and talent as a skilled communicator, but also because of his ability to experience this type of awe himself and to invoke it in others.

Carl Sagan [was] one of the greatest science communicators of the century. Why was he so good? Because his words made you feel like he was also constantly marvelled at the universe. Constantly! Every day that he woke up. He was in awe. (Int22)

As part of a motivational, affective, and narrative reward loop with curiosity-driven problem solving, awe was viewed by some respondents as being central to the science communication ethos. Such individuals tended to see themselves as awe experts, experiencing this emotion more frequently than the average person and readily being able to infect others with it. This version of awe appears to be an organizing pillar of much of the culture of science communication, constituting the affective nexus between a specific set of value-driven social practices (e.g., the science narrative), mandates (e.g., authenticity, openness to experience, sharing), and people's sense of identity within this cultural space.

3) *“everyone understands the feeling of wonder which we get when we do science”* **(theme - admiration)**

Somewhere between the last two themes appears a smaller theme in which scientific discoveries, technical inventions, and explorations in the name of science are represented as inherently ‘awesome’. Whether it is space rocket launches (Int1), the power of modern computers and phones (Int16), exploring the deep oceans (Int4), the Voyager probes (Int3) or a machine that can clean plastic from the ocean (Int19), most interviewees reserved a kind of awe experience that accompanied their admiration and esteem for the pursuit of science and its resulting ideas, objects, and practices.

As historians, anthropologists, and cultural critics have noted, it is through affective experiences that we assign value and constitute our relationships with other things in-the-world (Ahmed, 2004; Boddice, 2019; Lutz & Abu-Lughod, 1990). Scientific knowledge and technological artefacts aren’t inherently awesome but rather, we make them awe-inspiring through our affective discourses and practices. The ways in which we speak about scientific endeavours and outputs help to fuel this sense of admiration. These discourses of awe-as-admiration in science communication can turn “even a worm” (Int3) into something awesome. Arguably, the affective power of these expressions of awe through science is essential to the construction of much of science’s value in our societies; by cultivating a reverence for its progress and abilities, this emotion serves to maintain science’s status and reproduce its embedded social hierarchies.

For example, much of this admiration is reserved for objects at the frontier of scientific inquiry. This results in a hierarchy of sorts where astrophysics, genetics, robotics, artificial intelligence (Int13, Int10) and other fields that appear to be the vanguard of science are described as the bigger source of awe, while practices such as social and health sciences are described using other emotion categories such as interest, anger, and sadness (Int15, Int19). Hence lies the enormous power of this cultural discourse of admirative awe, whereby language can turn our attention towards certain objects and disciplines, turning them into ‘marvels’ worthy of reverence.

Science oozing reverential awe is reminiscent of Nye’s (1994) technological sublime. Derived from Kant’s mathematical sublime, it assigns the products of human reason (i.e., science and technology) the cathartic characteristics of the natural sublime (see chapter four). This type of awe of science is oftentimes displaced towards the figurehead of the engineer or the scientists, who becomes a source of awe in their own right. In this way, some interviewees expressed their awe towards scientists they have met or heard things about (Int9, Int15, Int20). The transfer of awe, however, does not stop at scientists, but continues by association to make science communicators themselves the source of awe. One particular example of this transfer is the case of Int7 who works as a scientist but does science communication activities on the side. This person expressed their desire to inspire awe in other people.

"I don't know if it comes across as arrogant to say, I want to inspire awe. I want to be awe-inspiring in people." (Int7)

The science communicator in their closeness to science, the ultimate source of awe, receives some of that awe-inspiring aura becoming themselves a source of admiration. The scientist who is also a science communicator is a greater source of awe than the person who is exclusively a science communicator, again, reproducing a hierarchical structure that this veneration confers.

In its conference of status, this particular kind of awe is instrumentalized in the maintenance of various practices that aim at ensuring the general support for science. One such practice is building a future workforce of scientists. Science communication organizations and national bodies understand the importance of promoting science for future national competitiveness (e.g., Bodmer, 1986) and exert their influence on science communication activities. As one participant told me:

"the commissioners that we work with from, for example, zoos, or for example, the science museum here, they try to say [...] keep in mind we have to create a positive message about science in general [...] to also show how amazing science is and to sort of recruit the scientists of the future. So, the result of that in exhibitions, is mostly that they should evoke amazement about science. (Int19)

Rather than an end in itself, evoking amazement, wonder, awe, and all other such emotions at a science communication event are tools for the advancement of particular social and political agendas through which science gets the human capital needed for its sustenance. Awe as admiration at science is then one of the tools through which science acquires the various forms of capital from which its status is established and reproduced in our societies.

By contrast to the previous themes where the source of awe was a surprising yet manufactured event at the beginning of a science show, or a carefully crafted narrative that led to awe, here science itself is represented as the ultimate source of awe. Much of the value that we assign to science in our societies is cloaked in the affective discourses of awe as admiration and reverence that we deploy as science communicators. Certain objects, by their association with science, become sources of this powerful emotion, facilitating and legitimizing various aspects of science's own hierarchies (e.g., the 'hard' sciences being more venerated than the 'soft' sciences) ensuring the continuation of its public support, and overall contributing to the sustenance of science's status in our societies. More importantly, in its instrumentalization it legitimizes many of the social practices to advance particular political and social agendas, such as the acquisition of the human capital needed for science's sustenance.

4) *"even the most brilliant museum is a prosaic environment compared to standing in the eye of a hurricane or standing on the lift of the Grand Canyon"* **(thread - revelation)**

While the technological sublime appears in the previous theme, the Burkean natural sublime, with its repertoire of over-the-top appraisals and strong religious undertones around beliefs of transcendence and revelation, continues to have an influential presence in the communication of science.

During the interviews, some participants described people's emotional experiences as being on a pyramid. At the bottom there is surprise and excitement and as you move up this "ladder of emotions" (Int17) you arrive at wonder. At the pinnacle of this emotion order lies 'true' awe, an experience that signifies a breakdown of normalcy and the trespass into other states of consciousness. Int11 explained:

"It's sort of like the limits of emotion. It's the limit of the capacity of the emotions to experience. Awe takes you to the edge of your emotional capacity to experience I think that's maybe where I would get with awe. To a point that goes beyond (.) it is certainly, the emotions are so expanded, they go beyond their own nature to something transcendental" (Int11)

In this representation of awe, its aesthetic is defined in terms of a long list of themes related to Burke's discourses of the natural sublime. These include complexity (6 participants), contrast (4 participants), dissonance (5 participants), powerlessness (4 participants), and vastness (14 participants). These are accompanied by descriptions of ineffability, incomprehension, and the numinous, religious motifs which pervade descriptions of this representation.

Examples of revelatory awe are common in biographies of scientists, especially when signalling biographical turning points that inspired the person to embark on a scientific career. One participant, for instance, described a young Leonardo Da Vinci "finding whale bones embedded in the wall" (Int4) as a life-changing moment, with his revelatory discovery being infused with awe. As with other aspects of scientific rhetoric, the language used to talk about such unique experiences connotes secularized versions of traditional expressions of religious experiences (see Lessl, 1989). As two participants noted:

"it is probably the nearest thing I guess that non-religious people get to something akin to the feeling that people have in sort of ecstatic religious experiences" (Int3).

"So, to me, awe is (.) getting close to God if you wanted a spiritual aspect (.) it's that which is beyond ourselves (.) beyond our ordinary thing." (Int11)

Descriptions of extraordinary emotional experiences of transcendence and ecstasy in nature mark the road of conversions and transformation into a life of scientific interest – narratives of inspiration that strongly mirror many traditional Christian myths of revelation. The Burkean sublime, a deeply religious aesthetic (see also, Cronon, 1996), is then a scaffold used in science communication through which religious elements are introduced to scientific rhetoric. This discourse seems to resonate deeply with people with non-religious beliefs who might still hold religious temperaments and who wish to consecrate science into a new form of religion (Sideris, 2017).

From a practical perspective, practitioners cannot easily elicit revelatory awe from their audience, as its source lies mostly in nature. It can be facilitated, however, with tools from science and technology that reveal nature's extraordinary power and scale (e.g., images of space from the Hubble telescope, or microbes under the microscope). As such, this version of awe tends to be reserved for the very large (e.g., black holes, supernovas, exoplanets) or the very small (e.g., mosquito larvae, neutrinos). This fact may reinforce the higher status of certain sciences that deal with such extraordinary matters (e.g., physics, astronomy, microbiology) (A. G. Gross, 2018; Kessler, 2012). Science communicators are then conduits for enabling people to experience these lofty emotions by giving their audiences access to nature in all its glory. Yet this is often something that only those with the most resources can provide, such as Brian Cox with scenes from "mountains or cliff tops on a helicopter" (Int8).

Notably, various participants raised some issues with this type of representation. Some mentioned how this version of awe can have negative effects on people. One participant suggested that the dissonance and disbelief of an all-too-powerful awe experience could potentially be too much for some and get them to "disengage entirely" (Int9) from a situation. Another participant talked about not using this kind of awe in their work as they felt it made people feel small and "kind of dismissible", tending to dehumanize science and making it less "relatable" (Int5). More troubling was the mention by one participant that awe in science communication was many times represented to reach out exclusively to men (Int4). This comment appears to highlight some of the historically gendered attributes of Burkean aesthetics, which often excluded women from participating in these powerful experiences (see A.K. Mellor, 1993). The recognition of these issues by the participants suggests that some practitioners are moving away from such off-putting aesthetics.

5) *"I mean it's just very pleasant to be reconnected, it makes you feel whole again"* **(theme - connection)**

Another theme in the representation of awe by science communicators is that of connection. A story that multiple participants reported was that as a result of the lockdowns in relation to the COVID-19 pandemic, they had a moment of awe whereby they felt reconnected with flora (Int10), looking at the sky (Int11), or a family tradition (Int22). Others reported reconnecting through awe experiences with their inner child (Int6), or a particular ecosystem (Int21). Implied in these narratives is the impression that humans have lost connection with certain aspects of their existence, and that encounters with awe make them aware of this absence and serve to reconnect them with the world.

For most of the participants who described this type of awe, the point of (re)connection was to nature. According to these narratives, our urban lifestyles, our increasing screen times, our focus on work, have drawn us away from a natural world, and awe towards a certain kind of nature works as a balm to the many contemporary ills that this has brought. A couple of participants (Int1, Int16) specifically mentioned the biophilia hypothesis - the idea that humans are universally inclined towards nature and that reconnecting with it will improve their health (Kellert & Wilson, 1993). Awe researchers have been fond of this suggestion and have been devising awe-based interventions to treat people with depression, anxiety, and other mental health problems (e.g., Anderson et al., 2018).

The natural world, however, is not described using the appraisals derived from the Burkean sublime (i.e., vastness, power), but rather with evaluations related to the discourse of the wondrous (see chapter four). These include descriptions of beauty (11 participants), smallness (7 participants), familiarity (4 participants) and silence (3 participants), among other descriptions highlighted in the previous section. Situations that are at a human scale, approachable, comforting, and rather ordinary were favoured. These situations make people really "look closely at what's around" (Int4) and develop an "intense focus" (Int21) from which "even familiar things" (Int1) can become objects of awe; scripts of defamiliarization described by many commentators (see Economides, 2016; Vasalou, 2015).

The job of the science communicator is seen as fostering situations through which this new perspective towards the familiar can be cultivated. Describing a workshop at a science centre, one participant explained how they tried to encourage feelings of awe and wonder at a small-scale event:

"we did a workshop where it was looking at planting native species, or potting moss and it was like this very small scale, hands-on, tactile thing. But they were very much focused on

getting people to observe and notice things that they may have not noticed before, like moss […], and I think you can still have those moments of awe and wonder at looking at something that you might have overlooked before as well." (Int1)

Such experiences cultivate a sense of wonder in "everyday nature" (int4), from which new relationships around care and protection can develop (Int10) and reconnect people in a way that "makes you feel whole again." (Int16). This theme resonates with those ecological discourses that deliberately use such emotions to foster beliefs and identities around an environmental consciousness (e.g., Economides, 2016; Moore, 2005).

This form of representing awe, nevertheless, is in tension with other ways of representing nature in science communication. On the one hand, entertainment forms of awe that portray pristine nature can particularly dull down forms of environmental and political action around the engagement with ecologies "under threat because of some human action or political situation" (Int1). On the other, representations of nature through the Burkean awe variety can contribute to the disconnection and alienation that disengages people, not just from nature, but from science altogether (Int5, Int9). Beautiful, familiar, pastoral, and quotidian aesthetics that engender feelings of awe and wonder, and which focus our attention on the present moment and reconnect us to our immediate surroundings, can serve, perhaps, as a counter to the diverting and disaffecting effects of some of these other discourses and aesthetics of the sublime variety (Economides, 2016; Moore, 2005; Sideris, 2017).

6) *"we are just this tiny little spec"* **(theme - humility)**

In 1994, Carl Sagan gave a speech about the Pale Blue Dot picture taken by the Voyager 1 space probe. The main theme around that speech was that as human beings have learned more about our unimportant role in the large scale of the universe, this process of gradual decentring leads to a new form of humility (for an elaborated discussion, see Sagan, 1997).

A few interviewees described appraisals during awe experiences accompanied by a sense of thinking of "a bigger picture" (Int4) or "of the world and the universe" (Int5) that gives them a sense of "feeling very small, that your problems, your existence seems very small" (Int3). Such imagery akin to the Pale Blue Dot encourages a sense of humility towards existence in the movement of the individual's frame of reference away from the centre. As one participant described:

"I feel a common example for people would be like thinking about space [...] But that quite often uses awe, and it is the idea that like we are just this tiny little spec, so that's, like in the whole universe and I feel that is like a change in someone perspective." (Int10)

By contrast to space imagery that aims at transcendent experiences with sublime aesthetics (e.g., Kessler, 2012), the Pale Blue Dot perspective comes in the form of rather more humane realizations such as those about the limits of human knowledge (Int7), that you play a small part of a larger scheme (Int5), that you are lucky to be in your current position (Int15, Int22), and that there is a lot of work left to do (Int20). This newfound humility nonetheless gives meaning to the individual, motivating them to contribute to the enormity of the human task and at the same time constructs their identity around a "shared human experience" (Int3)[108]; universalist and communitarian values found in much of the science and science communication ethos (see Medvecky & Leach, 2019).

7) *"there is just so many ways of doing it"* **(theme - other)**

Several respondents referred to awe in ways that did not readily match the foregoing themes. Although not as frequent as those already described, two particular representations are worth noting, what might be called *imagination*, and *national pride*.

A couple of participants described awe in terms of imagined worlds, for example when observing the Manhattan cityscape (e.g., "very sort of Blade Runner", Int3), or mentioning science fiction films as being a source of this emotion ("many possibilities out there that are way beyond our imagination", Int13). There are various aesthetics in science fiction that tend towards "wonder, awe, and religious or quasi-religious attitudes towards the universe" (Russ, 1975, p. 116). Although these might match functions similar to those given by sublime visions of awe, the repertoire that accompanies such representations is not of actual nature,

[108] Religious discourses of wonder around humility and gratitude as a result of a sense of smallness have existed through the ages (see Daston & Park, 1998). Considering the religious character of much of Sagan's rhetoric (Lessl, 1985) it wouldn't be surprising that Sagan's speech can be directly traced to those discourses. This, I believe, is an interesting topic for future research.

but of fictionalized 'what if' representations. The relation of these fictionalized worlds to science and science communication, and their use of awe, is a promising area to explore.

Moreover, one participant associated awe with national pride (Int20). This individual saw their efforts of communicating the science of researchers from their country as a nationalistic endeavour, designed to generate awe and, as a result, boost patriotism. This contrasts with the universalist and cosmopolitan values attached to some of the previous themes, and which are themselves connected to traditional scientific norms (e.g., Mertonian norms). Nonetheless, this theme has been previously noted by Nye (1994), who observed the use of sublime aesthetics in how the United States represents scientific pursuits and this nation's explicit beliefs in manifest destiny (see also, Kessler, 2012).

There were yet further, idiosyncratic representations of awe, oftentimes coloured with other emotions. For example, one participant expressed a sort of melancholic awe at graveyards (Int5), while another described a mixture of disgust and awe for creepy crawlers (Int 4). The study of these smaller ancillary themes around awe, and how these relate to the communication of science, is a task for future research.

8) *"that's not going to appeal to everyone"* **(thread - diversity)**
Many participants described awe and other emotions as if these were natural kinds in line with the classical view of emotions. Such description involved, for example, scientific ideas:

"But you know overall everyone would feel a sense of awe, to a great or a lesser extent when faced with something amazing like a view of a black hole." (Int8)

Or nature:

"It is easy to feel in awe with the environment because it is awe-inspiring. I don't know why. I think it just is. I can't explain it." (Int15)

Whether explicitly or implicitly, many participants described awe as an innate emotion that people felt automatically and instinctively when presented with awesome science or nature.

Nonetheless, a few participants had a more flexible and open understanding of this and other emotions. Besides some of the previously noted criticisms that some participants levied against specific forms of awe in science communication, some interviewees highlighted, for example, how the representations of this emotion were not going to appeal to everyone (Int4), that people are going to experience it in relation to their personal interests (Int10), and that there is not "a certain template associated with awe" (Int14). As one participant pointed out when describing the reaction of another person:

"so maybe she wasn't prepared for that, to have awe herself, I think it does impact people differently and in different times of their lives and their life experience." (Int21)

The belief that people markedly differ in their ability to experience awe as a function of their previous experiences is central to the constructionist view of emotions. Aware of the relative nature of emotional experience, another participant described how the focus on awe in science communication has "squeezed out" other affective possibilities from this cultural space.

"everyone's got the full range of emotions, and I think, maybe that's been squeezed out in science communication, everyone is focused on the wonder and awe, and squeezed out the rest." (Int4).

While still using awe and wonder in their work, this participant tried to incorporate "loads of different emotions" (Int4) as a means of engaging everyone rather than a narrow subset of the audience. Similarly, a few participants described how they stayed away from awe altogether in their work (Int5, Int19). These participants described appealing to other emotions instead, such as happiness, fear, anger, joy, and sadness; emotions that can humanize science and make them more relatable to people's affairs (Int4, Int5, Int19). These expressions suggest a general concern with diversity, wherein the emotional content of science communication is tailored not just for one kind of person (e.g., middle-upper class, straight, male, white) (Int2, Int4, Int5, Int19), but meant to appeal to the many individual lifetimes of experiences that every person who engages with science communication brings to an event.

7.4.3. Discussion

The participants described a variety of converging representations of awe in science communication. I organized these representations under the headings of entertainment, curiosity, admiration, revelation, connection, and humility. Versions of some of these themes are already found in the literature on awe and somewhat correspond to some of the descriptions of awe as discussed in chapters two and four. For example, the theme of connection has received increasing attention in recent years (Goldy & Piff, 2020). The theme of admiration here also somewhat resembles both themes of 'virtue' and 'admiration' explored by Keltner and Haidt (2003). The theme of revelation is similar to those descriptions in much of the literature connecting the role of awe and spirituality (e.g., Van Cappellen & Saroglou, 2012) while there has been a recent exploration of the relation between humility and awe (e.g., Stellar et al., 2018).

The classical view of emotions presents each of these themes as being aspects of a unified and universal emotional experience. According to this view, descriptions of awe at a moss workshop that develops into a sense of connection with the environment (Int1) are somewhat analogous to experiences of awe from pondering the scale of a black hole (Int8) and the accompanying beliefs on human transcendence. By contrast, I argue that there are enough differences between themes in the situations where each of these varieties get represented (i.e., form) and the things that these emotions do in the world (i.e., function) to be considered descriptions of different sociocultural phenomena altogether. For example, the situations where awe becomes active produced by a science demonstrator at a science museum (e.g., show with liquid nitrogen) (Int17) and tied to the goals of entertainment, have nothing in common with the quality and scope of the decentring of the human experience constituted through the 'awe-some' cosmic scales of the Pale Blue Dot speech (Int4, Int10). Each of these themes, I argue, stands for a different variety of awe.

The limited number of themes observed, however, is indicative of the degree of stability and consistency in the social representation of this emotion, something that applies to all social representations. As Bauer and Gaskell (1999) note:

"We stabilize representations of ourselves and of things in concert with others, with a shared pool of categorical perceptions, symbols, and conventionalized and habitual behaviour patterns" (p. 169)

The aforementioned varieties of awe are conventionalized frameworks (e.g., scripts, narratives, schemas) through which we make meaning out of this emotion category in this shared space. These local conventions of awe are historically contingent (see chapter four), and their use is tied to the individual's experiences and the cultural mandates operating during the situations where these emotions are represented. While individual experiences are for the most part idiosyncratic, the category's symbolic representation through language (i.e., the use of the word 'awe') and the various congruities in their social representation present a degree of contextual regularity, from which people acquire a certain degree of similar emotion knowledge that allows "good enough" (Casasanto & Lupyan, 2015, p. 544; Ferreira et al., 2012) communication to occur. Social representations establish a limit on the possible number of varieties that occur in one space.

The varieties of awe described in this section, however, were constructed in reference to the particular context within which the interviews took place (i.e., the culture of English-speaking science communication). While versions of awe around the themes of entertainment, curiosity, admiration, revelation, connection, and humility certainly exist in other cultural and subcultural spaces such as the world of art (e.g., Konečni, 2011), Christian religious communities (e.g., Krause & Hayward, 2015), or the tourism industry (e.g., Coghlan et al., 2012), the descriptions presented here have their own flavour in their localization within the particularities of science communication. For example, versions of awe as entertainment in science communication are very much tied up to the expectations of explanation at a science show or demonstration. This is different from other spaces where entertainment forms of awe occur (e.g., magic shows, circuses) (e.g., Lamont, 2017) where there is no elucidation of the objects in question. These particular ways of representing awe in science communication are in ways unique to this space as a result of these being tied up to its specific mandates (i.e., the norm and value of explanation).

The multiplicity of ways I observed this emotion to be represented is then a testament to the various mandate-based subcultures that operate within this larger cultural mosaic. Some of these themes can be associated with the subcultural spaces around the Public Appreciation of Science and Technology (PAST) and Critical Understanding of Science in Public (CUSP) dichotomy (Perrault, 2013). For example, the theme of admiration is committed to the reproduction of a black-box view of science as a superior kind of knowledge that should be unquestioningly revered. Similarly, the revelation view of awe is suggestive of the goal of finding a secular replacement of religious authority with science (Sideris, 2017). Beliefs of scientism and ideals of technocracy, reminiscent of hierarchical mandates of the PAST, permeate descriptions of reverent and transcendent awe. Awe, within those types of social representations, contributes to the constitution of the axiomatic power science receives within those worldviews. By contrast, descriptions of participatory activities that foster a sense of connection through awe-like emotions or the promotion of critical attitudes towards human activities through awe-imbued pleas for epistemic humility, can be described as in line with the cultural mandates of democracy and scepticism associated with the CUSP.

From this perspective, reverential and transcendent awe would appear to be more in line with hierarchical deficit-style mandates such as the promotion of careers in science (through the status awe emotion confers to science) or changing public attitudes of science (through a devotion to its products and practices), while the connection and humility varieties could be identified with calls for dialogue and participation. Similar one-to-one correspondences between other cultural mandates and varieties of awe could be drawn out. For example, the themes around humility could be tied to the universalist or organized scepticism of Mertonian norms or a sense of connection to environmental beliefs such as the Gaia principle[109]. As I described in chapter three, however, this simple dichotomy doesn't fully capture the nuance and complexity of the many interacting, contrasting, and competing mandates active at any point during a science communication situation.

As Priest (2013, 2018), Davies (2021), and others have pointed out (e.g., Kappel & Holmen, 2019), an instance of a communicative practice can have multiple mandates such as strategic, economic, democratic, or entertainment goals all layered up within the same activity. A science communication situation is assembled in the interaction between the many affordances provided by the products and practices produced in part by the science

[109] The Gaia principle or hypothesis suggests that all organisms and physical systems are interconnected (Lovelock & Margolis, 1974)

communicator, the variety of individuals who bring a diversity of lifeworld cultures to a science communication event, and the many particularities of the day (see Davies, 2018, 2019). A science communicator who presents an image of the Hubble space telescope to get people to experience awe can have strategic goals (e.g., get more funding for space exploration), entertainment goals (e.g., give people a positive experience), and democratic goals (e.g., get more people to humbly understand their place in the universe) all wrapped up within the same communicative activity. Similarly, the audience member who conceptualizes awe in such situation can conceptualize this emotion using any of the cultural scripts (e.g., transcendence, connection, admiration) and their various accompanying values, beliefs, norms, ideals, and worldviews (e.g., scientism, democratic participation) available to them at the moment. The construction of the dominant or preferred set of social meanings for awe by the audience isn't guaranteed, with an individual's response very much a function of both their distance to that particular set of meanings (i.e., their lifeworld culture) and the many idiosyncrasies of the moment. Many cultural mandates are then present at the moment when the emotion awe is represented in the culture of science communication. These interact in multiple and unforeseen ways, sometimes complementing each other, sometimes competing for dominance, all of which is situated in the sociocultural realities of the moment when and where they are constituted.

It is also worth highlighting that "the stability" and continuity of the social representation of awe "is precarious" at best (Bauer and Gaskell, 1999; p. 169). On the one hand, the borders of a culture are always fuzzy, always in flux, continuously permeated and penetrated by new forms of meaning from the broader culture. For example, some of the themes constructed from the present interviews did not seem to correspond to those explored in most of the reviewed literature on awe. This was particularly true for some of the minor repertoires of awe related to futurism and national pride, which have only been hinted at in literature from disciplines outside of psychology (e.g., Nye, 1994, Russ, 1975). These repertoires, with their own history and idiosyncrasies, may be moving into the science communication space enriching the available representational resources through which science communicators can produce novel versions of awe. As such, the varieties of awe presented here can only be considered a snapshot in time (i.e., the early 21st century) as these will continue to evolve changing in meaning, value, and use with the passage of time.

On the other hand, part of this process of change in the content of social representations is the result of the creative ways through which concepts are combined to create novel representations that add to awe's repertoire. This creative ability can be observed in the ways participants mixed the different types of awe, in many cases synthesizing strands from various themes. For example, one participant was able to amalgamate multiple themes when describing the weather extremes in the planets of the solar system:

"*You can do it in a different way, you can do it by eliciting feeling one, by eliciting awe, by eliciting curiosity, which will then increase your involvement and participation.*" (Int22)

The themes of revelation and curiosity are wrapped into mandates of participation, all sequentially fused into one statement that constitutes a novel representation. The combination of elements from different representational repertoires to create original permutations is the normal state of affairs for the human conceptual system (i.e., conceptual combination) (see Barsalou, 2012; Hoemann et al., 2021). Again, the operation of multiple mandates (metaphysical beliefs, value of having an inquisitive mind, goals of involvement) indicates the complex ways through which these can operate at the same time. The porosity of the borders of the science communication space and the potential to construct an infinite amalgam of representations out of the existing representational repertoire highlights the non-existences of stable prototypes or unique representations but rather captures the vast diversity of combinatorial possibilities that an emotion such as awe can take in cultural context, particularly in an increasingly diverse cultural space such as science communication. It is important then to not take the descriptions of varieties of awe in this taxonomy at face value but think of them in terms of broad social conventions (i.e., stereotypes) which are widely used today.

Finally, it is worth highlighting that one main criticism participants had about the use of awe in science communication is encapsulated by the theme of diversity. This theme recognized that people bring a variety of interests, experiences, and emotional lives to the science communication event, and that science communicators should be more attuned to this range. This criticism underscored that the kind of goals that science communicators bring to their communicative activities (e.g., fostering curiosity, promoting careers in science, changing attitudes towards certain topics, increasing participation) can be at odds with the way awe, wonder, and other such emotion categories are conceptualized as 'tools' to achieving such goals (see also Davies, 2019). The value placed on this particular brand of affect may limit the science communicator's ability to achieve their communicative goals as a result of these representational types already being preloaded with, and embedded within, distinct mandates. For example, the alienating effects of transcendental representations of awe described by some participants (Int5, Int9), could have been the result of the contrast between the product (e.g., images of the vast cosmos) and its cultural goals (e.g., realize metaphysical aspirations), and the immediate intended communicative goals of the communicator (e.g., fostering a sense of community, presenting a relatable image of science). In such situations, the interpretative frameworks that people bring to construct awe might be at odds with the intentions of the science communicator.

A skilful science communicator might be attuned to choosing the variety of awe that aligns with their specific communicative goals and the emotion knowledge brought by the participants. Defaulting to the varieties of awe, however, might not be the best way to achieve such goals as there is only so much that such stereotypes can do. There is a very large spectrum of other emotions (e.g., fear, love, anger, joy, nostalgia, camaraderie), and their many varieties, that do many different things within our cultures. Their functional range is above and beyond what awe, wonder, marvel, and other such emotions can do. The communicative goals in a particular situation might be better aligned with the functions provided by another emotion category. This might be particularly true for goals of making science communication more inclusive and diverse (see Canfield et al., 2020). People bring the full gamut of emotions to the science communication event, and these don't necessarily correspond to the stereotypical representations of awe presented in this chapter. Rather than expecting participants to experience knee-jerk awe reactions at the science communication event, products and practices that aim at fostering participatory spaces where people are not feeling 'left out' (Humm et al., 2020) can engage with people's emotion experiences and work with the wealth of knowledge that these bring.

7.5. General Discussion

My QCA analysis identified how science communicators ascribed a large variety of elements of experience to awe situations. By contrast to the classical view of awe, which argues for a very limited set of situations in which people experience awe, constricted by the appraisals of vastness and the motivational construct of need for accommodation (e.g., Keltner & Haidt, 2003), I found that many awe descriptions in science communication deviated widely from the norm. Take, for example, the experience of one interviewee who experienced awe mixed with pride at eating a courgette they had grown (Int22) and contrast it with the description of ineffable awe felt by another participant experienced when viewing a sunset and contemplating "the empty separation between myself and the sun" (Int11). These two situations could not have been more different, yet the referent used by both was the word 'awe' to describe them. The classical view would either dismiss one of them as not real awe (Keltner, 2009) or rather argue that one or both were making a metaphorical construal of vastness and need for accommodation (Graziosi & Yaden, 2019). Representational diversity of awe forms in science communication appears to be the norm, and with this vast contextual range comes a diversity of functions, including the use of this emotion to capture attention, for learning, building a relationship with science, constituting an autobiographical memory, or one of the many other goals described by the interviewees.

In the RTA analysis, however, I have reported certain common patterns in the stories told by participants surrounding their personal experiences, beliefs, and intentional use of awe's many instantiations to invoke an audience response. These common themes highlight how the emotional experiences of people are not just random but rather operate within the conventionalized social representations that are valued in the cultural milieu in which these are represented. That most participants referred to the themes of curiosity (21 participants) and entertainment (18 participants) suggests a broad culture of science communication in which some social representations of awe remain relatively consistent. However, the appearance of at least six other awe-based themes speak to the diversity of mandate-based subcultural spaces within science communication, each with different, often interacting, sometimes competing values, beliefs, norms, goals, and worldviews.

These findings resonate with the research on the constructed nature of emotions in relation to their cultural environments (e.g., Boiger et al., 2013), but also studies examining the different mandates that organize a culture of science communication (e.g., Davies, 2021; Perrault, 2013). Whether it is entertainment, revelation, or admiration towards science, these social representations differentially organize communicative practices and products around a variety of mandates. The implication of such strategies, in terms of their effectiveness and their political and ethical considerations, is a topic for future exploration.

7.6. Limitations

The present qualitative studies are limited by the use of a small convenience sample of interviews with science communicators. Although I applied criteria of diversity (e.g., gender, scientific discipline of interest) in the selection of the final participants, this still does not fully capture the diversity of experiences of those who practice science communication in the English language. For example, while it included one person from Australia, the United States, and two other people outside Europe, for the most part, participants were in Europe and particularly the UK. Therefore, the sample at hand did not allow me to compare different groups of participants and make inferences about the different forms of representations across different sociocultural dimensions and the intersections of these. Moreover, disentangling beliefs of emotion, and autobiographical experiences in self-reported descriptions of an emotion situation is methodologically fraught (Robinson & Clore, 2002). Respondents' retelling of their experiences with awe were, in-the-moment, utilizing conceptual knowledge in ways related to the situation they were in when answering my questions. Many responses were therefore linked to the expectations generated by the situation (i.e., Zoom interviews with an 'expert' in science communication), perhaps moving interviewees towards expressing stereotypical representations around their beliefs, rather than reconstructions of events. Finally, guided by the research question (i.e., how do science communicators talk about awe?) the questionnaire had little exploration about what science communication meant to the participants and what values they held in relation to this cultural space. This could have allowed for a deeper contrast between people's construction of the cultural mandates and their representation of this emotion category. Although this lack may have limited my ability to study the larger formations and worldviews in which the various scripts of awe operate, there is no guarantee that asking participants point-blank about their beliefs or values would have not devolved into commonplaces and platitudes generated by the expectations of the interview setting.

7.7. Conclusion and future directions

In this chapter, I observed that science communicators both hold a large variety of knowledge about awe and that it clusters mostly around a few common themes. Although exploratory, these findings raise multiple questions about the overall social representations of awe in science communication and more broadly about the conceptualization of this emotion in the literature. Future research on the representation of awe by science communicators could include participants with contrasting backgrounds to compare their differences in representational repertoires. Moreover, better distinctions can be made in the questionnaires to disentangle their personal experience with the emotion, their beliefs about awe, and their communicative practices to elicit the emotion in audiences. Importantly, future work can also try to work with groups that were not captured in the sampling. For example, purposefully incorporating conservative practitioners or people with different educational backgrounds can perhaps capture a larger swath of representational repertoires beyond those presented in this chapter. This is especially important for practitioners from other English speaking nationalities such as Aotearoa New Zealand who might have idiosyncratic ways of representing this emotion that are tied to their various local mandates such as integrating science with traditional forms of knowledge or communicating to bicultural audiences. Lastly, future research can focus on the larger cultural mandates around science communication that permeate the science communicator's representation of awe, by asking direct and indirect questions regarding their understanding of this cultural space and their various beliefs, values, and identities surrounding their practices. This last can also help us understand the role of science communication within a larger sociocultural matrix.

Chapter eight - Conclusion

8. General results

At the beginning of this project, I set up to answer the question: what is the nature of awe in the culture of science communication? Over its course, I have described this emotion's history, the value of its representation in this space, and its cultural specificity. I have also observed how people who participate in this culture develop awe as a skill and the variety of ways in which this emotion is represented. Based on the collective findings reported here, ten points can be made about the present thesis' contributions to our understanding of awe in science communication.

First, chapter five showed that awe is frequently represented in children's picture books aimed at communicating science. This prevalence indicates that awe is a valued emotion in this cultural space. As a valued emotion, people who participate in the culture of science communication will encounter awe often and seek out situations where they can practice this emotion.

Second, this means that in their repeated encounter with awe, people who participate in this cultural space become more skilled in its representation. The results in chapter six, where I evaluated people's ability to represent awe through a word association task, suggest that people who engage with science communication – going to science museums, watching science documentaries, listening to science podcasts – are cultivating this emotion in their consumption of these cultural products. This could also mean, and this in line with the results reported in chapter five, that children exposed to science picture books could be getting a head start learning this emotion. While this is not the only cultural space where this emotion is valued and where people can learn and practice it, science communication spaces may be enculturating and acculturating people in the representation of this emotion.

Nonetheless, and this is my third point, the representation of this emotion in science communication differs from that outside this cultural space. I observed qualitative differences in the content of both the social (chapter five) and mental (chapter six) representations of this emotion relative to a person or artefact's closeness to this cultural space. For example, awe seems to be represented more frequently in science communication using natural kinds (e.g., trees, mountains, galaxies) or in situations where the person is alone. These differences highlight the distinctiveness of the shared meanings that make up what I call the culture of science communication[110].

Fourth, I observed a variety of awe types in science communication. The studies in chapters five and seven, where I analysed the features of awe situations in picture books and interviews with science communicators respectively, suggest that there is no one stereotypical description of this emotion in this space, but rather that this emotion takes a multiplicity of forms and functions. For example, although awe was frequently represented in relation to large and imposing astronomical objects (e.g., planets, galaxies), it was also often presented in situations that were quotidian and familiar (e.g., looking at flowers). These studies also showed a diversity of settings (e.g., nature, built), events (e.g., entertainment, private), affective characteristics (e.g., positive or negative valence), and actions (e.g., approaching an object, moving away from the object) that relate to this emotion. Similarly, awe showed a variety of functions such as assigning value to scientific objects, motivating curiosity, inspiring careers in science, creating expectations around a technology, and integrating people's identities. Such a variety of forms and functions for awe is indicative of the diversity of beliefs, values, goals, and other cultural mandates that people hold around science communication. Although describing science communication as a culture, I would argue, is a good heuristic to describe a series of broad shared cultural meanings, these results highlight the mosaic of cultural and subcultural spaces around divergent mandates that make up this domain.

However, and this is the fifth point, while there was a degree of diversity in the many mandates associated with awe, there was also some degree of convergence around a limited number of representational types in science communication. The most common of these varieties of awe described in chapter seven, circled around the themes of curiosity, entertainment, admiration, revelation, connection, and humility, each of which is co-constitutive of different cultural mandates. For example, the admiration and revelation themes of awe could be said to reflect some uncritical and hierarchical views of science (e.g., naïve realism, technocracy, scientism) such as those of the Public Appreciation of Science

[110] Again, it is worth repeating that I am strictly referring to the culture of science communication in the English language.

and Technology (PAST) movement (Perrault, 2013). Similarly, the themes of connection and humility could be described as co-constructing participatory and critical views of science. It is worth noting, however, that these varieties of awe are idealized types (i.e., stereotypes) and don't capture the full extent of the myriad ways in which different cultural mandates interact, complement, and compete in a science communication situation.

Sixth, I argued in chapter four that these varieties of awe in science communication each have their historical trajectories that tie them up with the larger sociocultural contexts in which science communication occurs. Of particular importance are the aesthetics and discourses of the 'sublime' and the 'wondrous'. These formations have had a long and complex history of involvement in the constitution of awe in science communication in the English-speaking world. For example, discourses of the technological sublime and environmental wonder demarcate and constitute many of the contemporary ways we talk about technology as worthy of our awe-inspired admiration and the environment as a wonder-filled place to reconnect. These historical conventions delimit the conceptual space through which practitioners of science communication produce their awe-filled products and practices. The consumption of these social representations constitutes the knowledge through which those who engage in this cultural space can then construct their emotional experiences. Notably, some of the conventions of awe derived from the sublime and the wondrous observed in chapters five and seven, such as those representations of the white male solitary explorer as the sort who embodies this emotion, the use of this emotion to hype up science, or in ways that sugarcoat the environmental impacts of our science on the planet, continue to have a voice in this cultural space. These rather detrimental representations are in part the by-product of the sociocultural and historical baggage that some of these discourses (e.g., the natural sublime, the Kantian sublime) carry within them. The compatibility of some of these hierarchical and exclusionary representations with deficit-style science communication views, could be undermining the many important goals of those who hold democratic and participatory views of science communication, such as inclusion, equity, and environmental awareness (Canfield et al., 2020; Perrault, 2013; Polk & Diver, 2020; Sideris, 2017).

The seventh point I want to make is that if cultivating awe is a choice, there are a variety of ways of representing it, and each of the varieties co-constructs a different set of beliefs, values, norms, goals, and worldviews, means that awe has ethical and political dimensions.

Experiencing transcendent awe for Einstein's ideas or reverential wonder for Elon Musk's engineering projects are not knee-jerk reactions to evaluating something as vast but rather the result of having learned the scripts through which a situation of encountering those objects is interpreted as 'awe-some'. Versions of reverential and revelatory representations of awe may co-construct uncritical views of science which have a variety of social consequences through the accompanying beliefs, values, and norms that these promote. This includes issues such as generating improper expectations by hyping science (Perrault, 2013), describing those with differing beliefs as problematic and in need of a fix (Blue, 2018), and extending undeserved scientific claims to normative domains in policy-making activities (Welsh & Wynne, 2013) among many other things. Similarly, versions of awe that foster a sense of connection or epistemic humility can have a different set of social consequences such as helping us address some of our current environmental and social injustices (Sideris, 2017). Promoting and cultivating the affective scaffold for different mandates and worldviews with diverging political, economic, and social consequences makes the choice of a variety of awe over another a profoundly ethical one.

Eight, the results presented in this thesis also contribute to our understanding of awe more broadly. The variety of elements of a situation observed throughout the studies indicates that while there are cultural conventions that resemble many of the descriptions of this emotion in the classical view, these are only a proportion of the totality of repertoires available for its social and mental representation. For example, an evaluation of vastness and the outcome of accommodation were observed across the board in the three studies. However, these were not the only appraisals or goals observed in the representation of awe found in the studied picture books, word association norms, and interviews with science communicators. Throughout the studies, I also observed elements of awe situations that have fleetingly appeared in the extant awe literature, such as beauty (Keltner & Haidt, 2003) and uncertainty (A. M. Gordon et al., 2017). More importantly, I observed elements such as evaluations of ugliness, funniness, and fragility, and descriptions of awe while alone, in a dyad, or in groups, which have not been discussed much in previous studies. A variety of functions were also observed for this emotion besides the stereotypical need for accommodation and the motivational structure around exploration and curiosity that it entails (Valdesolo et al., 2017). My thesis revealed functions such as assigning value to objects, influencing career decisions, coming to realizations or epiphanies, and generating national pride, that have not been deeply explored in the reviewed literature.

Nine, it is worth pointing out how the studies presented here move away from the narrow conceptualization of culture as part of the individualist/collectivism construct present in much of the emotion literature, including both the classical and constructionist views (e.g., Boiger et al., 2013; Matsumoto et al., 1998). Rather, in this thesis, I have focused on differences in the representation of emotion within subcultural spaces that are part of a larger linguistic culture, an approach that other psychology and cognitive science researchers are slowly adopting (e.g., Kraus et al., 2010). Overall, throughout this body of work, I have assumed a broad view of awe, one which embraces the diversity of forms and functions that this emotion takes in the different cultural and subcultural spaces in which it is represented (see chapter 3).

Finally, and to bracket the previous points, I want to reiterate the non-universal and contextual nature of the claims I've made throughout this thesis. The word 'awe' is an emotion category exclusive to the English language. While emotion categories such as '*asombro*' in Spanish, '*huşu*' in Turkish, or '*Ehrfurcht*' in German, have come to take some of the meanings of awe through cross-cultural dynamics such as translation, migration, and trade, these words have their own distinct histories and local semantic realities. The results presented in this thesis apply then only to the Anglosphere. More importantly, the results presented here have focused on the particular experience of the United Kingdom and the United States. On the one hand, the samples of picture books and individuals in the three studies came mostly from these two countries. On the other, the experience of these two countries anchors both the theoretical and analytical descriptions of the cultural mandates that constitute the various subcultures within the culture science communication. While the from 'deficit to dialogue and participation' narrative arc doesn't necessarily match the historical trajectory of science communication in many countries (see Gascoigne et al., 2020), I utilize this framework in many of my descriptions of the cultural mandates that constitute the different subcultures within the larger English-speaking mosaic. However, there are many other local subcultural mandates operating at the country level that fall outside the purview of those discussed throughout this thesis and which are based on the British-US experience. As a result, I caution against any generalizations beyond the experience of these two countries.

This is particularly important for a country such as Aotearoa New Zealand where the broad cultural mandates discussed throughout this thesis cohabit, compete, and mix with localized values, beliefs, goals, and worldviews (Fleming et al., 2020). For example, projects such as *'A Nation of Curious Minds'* sponsored by the New Zealand Government, contains goals such as the promotion of "STEM-related career pathways" and a more "scientifically and technologically engaged public" (Ministry of Business, Innovation, & Employment, 2014, p. 7) that are in-line with some of the deficit- and dialogue-style mandates discussed throughout this thesis. However, these mandates are intersected in this project by other outcomes such as the promotion of traditional Māori knowledge (i.e., *Mātauranga*) and fostering bicultural identities and values; goals that are unique to the histories and experiences of this particular local context. Whether the varieties of awe described throughout this thesis apply to the local sociocultural realities of Aotearoa New Zealand or any other circumscribed national context, remains an open question for future studies. Similar more focused studies on awe can take into account the intersectionality between cultural mandates within other sociocultural domains such as those demarcated by religious beliefs, political affiliation, gender, occupation, and class.

Together, the findings emerging from the foregoing studies indicate the value of awe in science communication, its cultural uniqueness and historicity, its enculturation and acculturation, and the variety of forms and functions this emotion takes within this cultural space; all factors that are in line with the constructionist view of emotions. Although exploratory, these findings advocate for a broader conceptualization of awe (and other emotions) that takes into account the sociocultural realities of the many contexts where this emotion is represented. In the following section, therefore, I discuss some reflections and speculations on the constructionist view of emotions and the predictive paradigm it is based on (see Hutchinson & Barrett, 2019) for the study of awe, the field of science communication, and the research on emotions in this field.

8.1. Implications for the literature on awe

Since Keltner and Haidt's (2003) seminal article, awe has become a subject of scientific inquiry in and of itself, with dozens of papers committed to a definition imposed by a very culturally specific representation of this emotion's meaning (i.e., an emotion caused by encounters with the large and imposing that results in a need to accommodate new knowledge). These authors defined this emotion on a culturally situated reading[111] of a sparse literature review that didn't look into people's actual lived experience or empirical data[112]. Rather than considering the many usages, histories, and conventions that this emotion has, most of the program of enquiry that their article launched has become unremittingly committed to these authors' narrow definition.

As Danziger (1997) argued about categories such as 'attitudes' and 'intelligence', "the naming of psychological categories is really quite arbitrary" (Danziger, 1997, p.6). From the findings described throughout the literature review, the historical contexts where this emotion has been represented, and the many descriptions it received throughout this thesis, there appears to be no one set of characteristics, neither of form nor of functions, which are common to all experiences of this emotion. For example, take the various descriptions of its affective character. Both descriptions of positive and negative valenced experiences have been described for this emotion. These match those in the literature, where previous studies have reported participants having both positive and negative feelings during awe inductions (e.g., A. M. Gordon et al., 2017) and which broadly correspond to historical descriptions of awe as both negative or mixed (Burke, 1990/1757) and positive (McDougall, 2015/1908). Similarly, this emotion was described both as positive and negative by the science communicators interviewed in chapter seven. Likewise, they described awe situations as mostly exciting but sometimes calming. Such affective dissonance linked to the same term also parallels results showing both sympathetic activation and withdrawal as part of this emotion's profile (e.g., Chirico et al., 2017; Shiota et al., 2011). Such apparent contradictions for the same emotional category have largely been brushed aside by researchers, for example dismissing awe as simply having a "novel and complex" profile (Shiota et al., 2014, p. 365), describing it as part of an altered state of consciousness (Yaden et al., 2017), presuming it to have both positive and threat-based variants (e.g. A. M. Gordon et al., 2017), or suggesting that some instantiations are not authentic awe (see Keltner, 2009). Certainly, descriptions of vastness and need for accommodation (Keltner & Haidt, 2003) correspond to one of the many scripts of awe that circulate in our culture. In my view, however, the field of awe studies should proceed in the same way as Barrett (2009) argues the field of psychology should, by

[111] There is no reference to positionality in any of their work on awe. This is intriguing considering how much attention, for example, Jonathan Haidt's has placed on issues of identity, ideology, and their effect on the production of knowledge (e.g., Haidt, 2012).
[112] I sometimes wonder whether the historical trajectory taken by the word 'awful' from having a somewhat positive to a very negative connotation gave the authors any pause in their conceptualization of 'awe' as a positive emotion with its associated moral significance.

beginning to "reconsider its vocabulary of categories" (Barrett, 2009, p.327) moving away from the view of awe as a 'natural kind' (Barrett, 2006a) and that arbitrary and narrow definition by Keltner and Haidt (2003).

Again, this is not to say that awe is not real or meaningful as an object of investigation[113]. Awe is real in the same way all "emotions are real" (Barrett, 2012, p. 413), as the result of the collective agreement of individuals that give it form and function within situations in culture. Reconsidering the vocabulary around awe would mean moving away from its reductionist conceptualization and treating it instead as a complex and holistic phenomenon (Barrett, 2013). For example, it can be treated as the result of contextually situated primitive psychological processes (e.g., categorization of elements of situations), in concert with social (e.g., acculturation of awe), cultural (e.g., discourses of awe) and historical (e.g., histories of awe) contingencies, that situate the biological body within the larger contexts in which it develops (see Boddice, 2018; Boddice & M. Smith, 2020).

More importantly, the work that treats this emotion category as *explanans* to a variety of phenomena such as prosociality (Piff et al., 2015), autonomic physiology (Shiota et al., 2011), memory (Danvers & Shiota, 2017), and information processing (Valdesolo & Graham, 2014), can be re-evaluated in terms of situated domain-general processes. Re-evaluating awe as *explanans*, however, does not entail discarding it altogether as a useful category for analysis in the social sciences. As a result of the highly complex and dynamic interactions of domain-general processes within a social and cultural setting, awe has emergent characteristics that cannot be reduced to just those domain-general processes (Barrett, 2013). Awe could be a useful category in relation to the level of explanation, analytical approach, and methods used to describe its components and emergent properties. The possibility of using awe as a category to explain phenomena, nonetheless, hinges on the ability to skilfully situate this emotion in context through 'thick descriptions' (Geertz, 1973) of the social-cultural practices, historical contexts, and specific situations in which the described processes occur. Taking the narrow view of awe characterised by the classical view as one of many scripts and moving towards a theoretical stance that places context front and centre will help

[113] Not that I don't have a sense of irony, but I would not have written the last two hundred or so pages if I believed this was the case.

to build much-needed bridges between psychology, sociology, anthropology, and history (see Boddice 2020a).

One final implication of sticking to the narrow conceptualization of awe presented by Haidt and Keltner (2003) is that it perpetuates hegemonic discursive and aesthetic formations of emotion that have deep, and often harmful, social effects. The imposition of a definition of authentic awe as requiring vastness and need for accommodation (Keltner, 2009; Keltner & Haidt, 2003) performs boundary work in its invalidation of people's experiences if they do not conform to such normative characterizations (see Lutz & Abu-Lughod, 1990). Experiences of awe described in terms of the small, the picturesque, the mundane, the familiar, and the beautiful, all of which are common in literature outside affective science (e.g., Economides, 2016; Sideris, 2017; Vasalou, 2015), and which were also observed throughout this thesis, do not conform to Haidt and Keltner's (2003) model. It is worth highlighting that these authors' characterization of awe is mostly based on a Burkean and Kantian sublime, which have been thoroughly criticized as sexist, ethnocentric, and detached from environmental concerns (e.g., Freeman, 1995; A. K. Mellor, 1993; Yaeger, 1989). The gender and racial differences in the representation of this emotion in children's picture books, as well as some of the interviewees' descriptions of awe, indicate the enduring prevalence of such stereotypes. These negative stereotypes, however, are being further emboldened by their implicit validation in highly cited scientific discourse[114].

Similarly, the classical view's narrow characterization of awe is thoroughly within the positive psychology discourse on emotions (Shiota et al., 2017), a hegemonic discourse well inscribed into injurious neoliberal narratives of the self, work, and life (e.g., Cabanas, 2018; Cabanas & Illouz, 2019). Despite the well-intentioned nature of much of the positive psychology work on emotions such as happiness, it has brought a host of increasingly documented adverse effects on people and society, such as anxiety, narcissism, and the reproduction of consumerist fantasies that are a driving part of environmental calamity we are now living in (e.g., Adams et al., 2019; Cederström & Spicer, 2015). For example, the promotion of awe as a cure for psychological ills (Anderson et al., 2018), and the ways in which the wellness industry has embraced it (e.g., F. Williams, 2017), puts the onus of 'being

[114] Unfortunately, the research program on awe based on Keltner and Haidt's definition (2003) seems hell-bent on reviving the Burkean sublime as a category of serious study (see Clewis, et al., 2021).

well' and self-improvement on the individual rather than on social and political structures driving inequality, poverty, and social breakdown, diverting attention away from the deprivations stemming from our sociopolitical institutions (for discussions of this issue in the context of mindfulness, see Hari, 2019; Purser, 2019). In short, embracing the classical definition of awe within larger, hegemonic, individualistic, and consumer-driven discourses of the self has consequences well beyond academia.

I believe it is imperative that scholars continue to interrogate essentialist claims about the 'true' nature of awe, remembering that such claims are based on specific cultural histories, such as the Burkean and Kantian sublime and the positive psychology movement. I encourage a broader approach that lends itself to a more comprehensive, and arguably more scientific, understanding of the many phenomena described in much awe-research, one grounded in domain-general processes within a predictive paradigm of psychology (Hutchinson & Barrett, 2019) situated in sociocultural and historical realities (Boddice, 2018). Such an approach injects emergentist, contextualism, and critical ideas to document not only individual, but also the broader societal effects of awe in the different situations in which it is represented.

8.2. Implications for science communication

Despite every attempt to redress its failures, the standard "deficit model" remains the dominant approach to science communication practices (Simis et al., 2016). Deficit forms of science communication are associated with naïve views of science, in which scientific knowledge is seen both as objective and detached (Perrault, 2013). Emotions in these models are mostly seen as tools that science communicators can use to achieve their narrow communicative goals (see Chapman et al., 2017) yet are not constitutive of the scientific knowledge conveyed. The classical view of emotion, with its separation between cognitive and affective mental phenomena (e.g., Ekman, 1992, 2003; Tracy & Randles, 2011), implies that knowledge can be disentangled from its affective mooring. Such an approach is reminiscent of the old Platonic distinction between reason and passion, emotion and thought, hearts and minds (Lutz, 1986, see Barrett, 2020). The deficit model view of knowledge is therefore compatible and supported by the classical view's take on human nature.

However, as philosophers and anthropologists have decried, and the constructionist view of emotion has validated, "all psychological events exist in affective space" (Hutchinson & Barrett, 2019, p. 287) (i.e., knowledge is affectively laden). Affect is a manifestation of allostatic regulation and serves as a domain-general process used in all cognitive processes (Barrett, 2017c; Barrett et al., 2014; Barrett & Simmons, 2015). Affect focuses our attention on the allostatically relevant objects in the environment and motivates action towards engaging with such objects, among other things (Gendron et al., 2020). More importantly, it is an aspect of every situation, grounding all knowledge in the body (Barsalou et al., 2018), ephemerally and inescapably working as "a feature of all concepts" (Gendron et al., 2020, p. 208). Work that shows the prevalence of interoceptive representation in all categories (Lynott et al., 2020) and the presence of micro-valences in even the most mundane objects (Lebrecht et al., 2012), are only a few examples showing that the boundary between cognitive 'knowledge' processes (e.g., memory, thinking, mentalizing) and affective manifestations such as emotion, is a cultural stereotype that has no basis in the actual functioning of the brain (Barrett, 2009; Danziger, 1997; Lutz, 1986). Deficit model approaches, then, are not just flawed in that they are ineffective at facilitating people's understanding of science (see Logan, 2001; Simis et al., 2016). They are also based on ontological assumptions about the nature of the mind and knowledge that are presently hotly contested in the psychological sciences. Including these latest developments is both warranted and timely for science communication endeavours.

Any training delivered to science communicators that is based on overly simplistic, weakly supported versions of the human mind, such as those in which cognition and emotion are seen as independent phenomena, is problematic (see Barrett, 2020). This is particularly the case as we continue to put expectations of public engagement on scientists and science communicators who endorse outdated rationalistic understandings of the mind, such as those peddling 19th century utilitarian economics (Simis et al., 2016). Courses for future science communicators should include modules on the latest understanding of the human mind, those that break with the popular 'faculty psychology' and rational choice frameworks which have dominated the cultural practices of the Western, industrialized worlds for so long (Barrett, 2009, 2017a; Barrett et al., 2019; Gendron & Barrett, 2009; Hutchinson & Barrett, 2019).

In addition, there are concrete implications of the prediction paradigm of psychological sciences, in which the constructionist view is inscribed (Hutchinson & Barrett, 2019), for science communication practices, particularly in relation to the current research on awe. Some of the most common types of awe in the literature (e.g., Valdesolo et al., 2017) and the studies in this thesis relate this emotion to categories such as excitement, surprise, wonder, curiosity, and learning – outcomes that are seen by many as desirable in science communication activities (e.g., Besley et al., 2016; Brown & Scholl, 2014; Davies, 2019; Metcalfe, 2019; Treise & Weigold, 2002). The uncertainty, arousal, and acquisition of new knowledge implicit in these categories have all been associated with prediction error – the updating of the brain's model of the world from unanticipated information (Barrett, 2017c; Theriault et al., 2020). Considering that much of the stated goals of science communication practices, particularly those of deficit model approaches, are related to giving new information and adjusting people's attitudes, beliefs, and knowledge (Bucchi, 2008; Metcalfe, 2019), much of the culture of science communication is dedicated to the promotion of situations where people's expectations are violated, requiring their brains to be constantly updating their internal model (i.e., prediction error). Many of the practices around some of the awe-types in science communication observed throughout this thesis are promoting these prediction error-related outcomes, which are at the centre of many, if not most, science communication practices.

However, prediction error in general, and that implied in these awe-types, is metabolically costly, and as such, the brain tries to avoid it in many situations (Theriault et al., 2020). The brain is continuously trying to balance its energetic resources and needs in its enactment of its internal model (Hutchinson & Barrett, 2019). As such, it is continuously trying to anticipate (i.e., predicting) its energy needs before they arise (i.e., allostasis), something that is efficient both in the short and long term (Barrett, 2017c; Sterling, 2012). Prediction error is part of the brain's normal functioning having a crucial evolutionary function of updating the brain's model in the encoding of new conceptual knowledge in memory to improve the accuracy of future predictions and anticipate energy requirements (see Barrett, 2017c; Spratling, 2017). However, updating the internal model from a mismatch between the input and the prediction uses considerable resources (e.g., glucose, water, ATP) taxing the nervous system in different ways as a result of the energy imbalance this mismatch generates, ultimately motivating people to behave in ways that avoid such imbalance (Theriault et al., 2020).

Awe-based science communication activities that are continually requiring participants' brains to update their internal models (i.e., generate prediction error) may then be overtaxing people's nervous systems. I believe then that the continuous imposition of situations with prediction error might be deleterious to getting more people to engage with science communication. If every engagement with science communication results in surprise, novelty, learning, or whatever other conceptualization in which prediction error is its outcome, including many of the awe-types observed in this thesis, many people's brains are going to associate this space with those metabolic costs incurred. As the brain predicts those losses before they arise, science communication spaces will be avoided by many. This, I believe, lies in many people's conceptualization of science as boring, difficult, or alienating, and their general lack of engagement with science communication. You could think of this hypothesis as the physiological and metabolic antecedents of "eww science".

If true, this hypothesis might have serious implications in the way science is communicated. Activities designed with science knowledge learning goals in mind and that use excitement, novelty, awe, and other tools to achieve such outcomes, may be repellent to people whose brains do not want to tax their physiological budget with a barrage of prediction error. The poor, the overworked, the stressed out, minorities, those who do not sleep well, the depressed, immigrants, people dealing with trauma, and all those who have an already strained nervous system (Barrett, 2017a; Fridman et al., 2019; Gendron et al., 2020) will find it even harder to engage with these spaces, thereby perpetuating many of the inequities in access already so present in the culture of science communication (Canfield et al., 2020). A science communication culture conducive to engaging as many people as possible should aim then to strike a balance between excitement, newness, hype, and learning on the one hand, and products and practices that are familiar, common, ordinary, safe, and monotonous, which do not ask too much of the many audiences, on the other. Awe-types that do not promote constant prediction error could be used to make people feel at ease in a science communication space. Of course, this needs to be contextually situated as the meanings of excitement, new, ordinary, safe, familiar, and awe change from place to place for the many different publics encountered by practitioners.

One such audience-based difference is age group. People have varying capacities to deal with prediction error at different points in life, and these align with developmental changes (see Hoemann et al., 2019). Whereas early infants have prediction error as their default setting, and children can take in a higher load of the energy mismatch generated by prediction error (Atzil et al., 2018), adults will increasingly avoid arousing situations that tax their energy budgets (Theriault et al., 2020). This would mean that engaging people with exciting and novel science and science-based activities will become more challenging as they grow older. Moreover, acculturation processes whereby people have to learn the conceptual knowledge through which they can participate in a cultural space (Gendron et al., 2020) become harder with age. This speaks to the importance of enculturating children early into social practices within this cultural space, thus normalizing the expectation of prediction error and incorporating these into the calculation of the energy expenditures required for interaction with this cultural space. Such a consideration reveals why science communicators must be cognizant of how the age group of their audience influences their capacity for engagement. Thus, it can help to create spaces that ‘soften the landing’, getting people’s brains to smoothly update the model and feel welcomed and comfortable in these spaces. Perhaps science communication practices could find ways of easing the energetic load and cognitive stress that comes with having to learn the conceptual knowledge with which to engage with a novel cultural space, by establishing points of familiarity and common ground, while slowly moving to the point where prediction error can occur. Essentially, science communicators’ willingness to adopt an energetically-aware appreciation of the old adage “know your audience” will be central for engaging many historically disengaged communities.

Many of the awe-types in science communication observed throughout this thesis are used as tools to teach new scientific knowledge, generate excitement for science, and maintain a stable workforce of scientists (i.e., deficit-style goals). Moreover, some of the types of awe described carry with them hierarchical and exclusionary mandates resultant from historical legacies. The combination of deficit-style goals, the hierarchical and exclusionary mandates surrounding certain varieties of this emotion, and the prevalence of its representations that impose high metabolic costs on people, might be contributing to many people ‘feeling left out’ (Humm et al., 2020) from participating in this cultural space. Moving away from a representational repertoire that perpetuates exclusionary mandates and establishes high energetic burdens for access is the appropriate direction for science communication practitioners with a democratic bent who want to 'preach' to those beyond the already converted.

8.3. Implications for the study of emotions in science communication

Finally, the constructionist view can contribute to the study of emotions in science communication. As previously highlighted, most of the work on the role of emotions in science communication defines these using mechanistic stimulus-response-output schemes derived from the classical view of emotions (see Chapman et al., 2017). Whether these are studies looking at the role of emotions in risk processing (e.g., Witte & Allen, 2000), the formation and change of beliefs (e.g., O'Neill & Nicholson-Cole, 2009), or behaviours (e.g., Yeo et al., 2018), these studies represent most of the work in the field of science communication. As I have highlighted throughout this thesis, the evidence for the theoretical and epistemological frameworks used in these studies is dubious at best. For example, guilt or fear shouldn't be interpreted as causing increased support for climate change proposals or creating motivations to engage with the topic (e.g., Bilandzic et al., 2017; Lu & Schuldt, 2015). Instead, some people will construct certain cultural scripts for these emotion categories in relation to their life experience and the laboratory situations in which the studies were set, through which they co-constructed the pro-environmental motivations, beliefs, and attitudes presented in the results. In other words, emotion categories are dynamically constituted in culturally-laden scripts to tackle a particular matter in a situation within a socio-cultural and historical context. Some versions of fear and some versions of hope might engender such responses, but 'whose fear and hope is this?' and 'where are these emotion conceptualizations happening?' are perhaps better questions to be asking. In this sense, I suggest moving away from the idealized laboratory paradigms used in many of these studies in which participants are primed in ways that supposedly elicit a discrete emotional response, with experimenters then measuring how this affective state influences their response to a questionnaire or a task (e.g., Bilandzic et al., 2017; Yeo et al., 2018). Future research can use ecological and ideographic approaches that consider the range of forms and functions that emotions assume within individuals and across the diverse set of contexts navigated by people in the real world (e.g., Conner & Mehl, 2015). More importantly, the study of these emotions could be accompanied by thick descriptions of the particular histories of the emotion types expressed by participants and the lives of those who construct them through qualitative or mixed methodological approaches (e.g., Braun & Clarke, 2013).

Addressing questions about people's feelings about a particular science policy, the affective value they assign to particular beliefs and motivations around science, or how to evaluate different emotion framings for a science-related campaign, requires a broader and more complex view of emotions than what is currently applied to these important issues. Ideally, this is one that does not treat emotions as "simple levers" or tools (Chapman et al., 2017, p. 850) to be pulled indiscriminately on an audience to generate axiomatic engagement responses or that assigns one-to-one functionalities to emotion categories, but instead puts context front and centre with the research agenda. Only then will the study of emotions in science communication be able to answer questions about how people relate affectively to scientific topics.

8.4. Final words

This thesis had an overarching research objective, which was to investigate the nature of awe in the communication of science. However, this topic also opened a space for me to learn about the study of emotions, awe, and science communication more generally. What I found at first was both dismal and encouraging. On the one hand, I found a field in turmoil, much of it unaware of its own cultural biases, and siloed in one academic subdiscipline. On the other hand, I found the excitement of a group of scientists standing at the cusp of a paradigm shift in our understanding of the human mind and its place in culture and society. This thesis has resulted from my humble attempt to catch the wave of this paradigm shift and begin to explore what it means to think of emotions as constructions and science communication as a cultural space. Leaving behind the many constraints and limitations of the classical view of emotions and its take on awe, freed me to observe and assess the special place this emotion has in science communication, the diversity of forms and functions it takes, its unique histories, and the contextual and situational nature of its varieties. It is my hope that future researchers adopt some of the ideas presented in this thesis and expound on them further, working together to develop a more detailed understanding of how people relate affectively to science within this revolutionary theoretical landscape.

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Appendices

Appendix A – List of picture book biographies

Title	Year of Publication	Biography of	Author	Illustrator
A boy and a jaguar[1]	2016	Alan Rabinowitz[3]	Alan Rabinowitz	Catia Chien
A passion for elephants[2]	2015	Cynthia Moss[3]	Toni Buzzeo	Holly Berry
A river of words: The story of William Carlos Williams[1]	2008	William Carlos Williams[4]	Jen Bryant	Melissa Sweet
A splash of red: The life and art of Horace Pippin[1]	2013	Horace Pippin[4]	Jen Bryant	Melissa Sweet
Ada Byron Lovelace and the thinking machine[2]	2015	Ada Byron Lovelace[3]	Laurie Wallmark	April Chu
Ada Lovelace, poet of science: The first computer programmer[1,2]	2016	Ada Byron Lovelace[3]	Diane Stanley	Jessie Hartland
Ada's ideas: The story of Ada Lovelace, the world's first computer programmer[2]	2016	Ada Byron Lovelace[3]	Fiona Robinson	Fiona Robinson
Ashley Bryan: Words to my life's song[1]	2009	Ashley Bryan[4]	Ashley Bryan	R. Gregory Christie
Bad news for outlaws : The remarkable life of Bass Reeves, deputy U.S. Marshal[1]	2009	Bass Reeves[4]	Vaunda Micheaux Nelson	Bill McGuinness
Balloons over Broadway: The true story of the puppeteer of Macy's parade[1]	2011	Tony Sarg[4]	Melissa Sweet	Melissa Sweet
Barnum's bones: How Barnum Brown discovered the most famous dinosaur in the world[2]	2012	Barnum Brown[3]	Tracey E. Fern	Boris Kulikov
Before John was a jazz giant[1]	2008	John Coltrane[4]	Carole Boston Weatherford	Sean Qualls
Between the lines: How Ernie Barnes went from the football field to the art gallery[1]	2018	Ernie Barnes[4]	Sandra Neil Wallace	Bryan Collier
Black Elk's vision: A Lakota story[1]	2010	Lakota-Oglala[4]	S.D. Nelson	S.D. Nelson
Buzz Aldrin. Reaching for the moon[2]	2005	Buzz Aldrin[3]	Buzz Aldrin	Wendell Minor
Caroline's comets: A true story[2]	2017	Caroline Herschel[3]	Emily Arnold McCully	Emily Arnold McCully
Charles Darwin's: Around the world adventure[2]	2016	Charles Darwin[3]	Jennifer Thermes	Jennifer Thermes
Come see the Earth turn: The story of Léon Foucault[2]	2010	Leon Foucault[3]	Lori Mortensen	Raul Allen
Confucius: The golden rule[1]	2002	Confucius[4]	Russell Freedman	Frederic Clement
Counting birds: The idea that helped save our feathered friends[2]	2018	Frank Chapman[3]	Heidi E.Y. Stemple	Clover Robin
Counting on Katherine How Katherine Johnson saved Apollo 13[2]	2018	Katherine Johnson[3]	Helaine Becker	Dow Phumiruk
Dare the wind: The record-breaking voyage of Eleanor Prentiss and the Flying Cloud[1]	2014	Ellen Prentiss[4]	Tracey E. Fern	Emily Arnold McCully
Dave the Potter: Artist, poet, slave[1]	2010	Dave the Potter[4]	Laban Carrick Hill	Bryan Collier
Diego Rivera: His world and ours[1]	2011	Diego Rivera[4]	Duncan Tonatiuh	Duncan Tonatiuh
Dinosaur mountain: Digging into the Jurassic age - Story of Earl Douglass[2]	2010	Earl Douglass[3]	Deborah Kogan Ray	Stock pictures
Dizzy[1]	2006	Dizzy Gillespie[4]	Jonah Winter	Sean Qualls
Drum dream girl: How one girl's courage changed music[1]	2015	Millo Castro Zaldarriaga[4]	Margarita Engle	Rafael López

Electric Ben: The amazing life and times of Benjamin Franklin[1]	2012	Benjamin Franklin[4]	Robert Byrd	Robert Byrd
Electrical wizard: How Nikola Tesla lit up the world[2]	2013	Nikola Tesla[3]	Elizabeth Rusch	Oliver Dominguez
Emmanuel's dream: The true story of Emmanuel Ofosu Yeboah[1]	2015	Emmanuel Ofosu Yeboah[4]	Laurie Ann Thompson and Sean Qualls	Sean Qualls
Enormous smallness: A story of E. E. Cummings[1]	2015	E.E. Cummings[4]	Matthew Burgess	Kris Di Giacomo
Farmer Will Allen and the growing table[1]	2013	Will Allen[4]	Jacqueline Briggs Martin	Shabazz Larkin
For the birds: The life of Roger Tory Peterson[2]	2011	Roger Tory Peterson[3]	Peggy Thomas	Laura Jacques
Frederick's journey: The life of Frederick Douglass[1]	2015	Frederick Douglass[4]	Doreen Rappaport	London Ladd
Frida Kahlo and her animalitos[1]	2017	Frida Kahlo[4]	Monica Brown	John Parra
Funny Bones: Posada and his day of the dead calaveras[1]	2015	Jose Guadalupe[4]	Duncan Tonatiuh	Duncan Tonatiuh
Gregor Mendel: The friar who grew peas[2]	2006	Gregor Mendel[3]	Cheryl Bardoe	Joseph A. Smith
Hammering for freedom: William Lewis[1]	2018	William Lewis[4]	Rita Lorraine Hubbard	John Holyfield
Handel: Who knew what he liked[1]	2001	George Frideric Handel[4]	M.T. Anderson	Kevin Hawkes
Helen's Big World: The life of Helen Keller[1]	2012	Helen Keller[4]	Doreen Rappaport	Matt Tavares
Hello, I'm Johnny Cash[1]	2014	Johnny Cash[4]	G. Neri	A.G. Ford
Hiawatha and the peacemaker[1]	2015	Hiawatha[4]	Robbie Robertson	David Shannon
I dissent: Ruth Bader Ginsburg makes her mark[1]	2016	Ruth Bader Ginsburg[4]	Debbie Levy	Elizabeth Baddeley
I, Galileo[2]	2012	Galileo Galilei[3]	Bonnie Christensen	Bonnie Christensen
Into the deep: The life of naturalist and explorer William Beebe[2]	2009	William Beebe[3]	David Sheldon	David Sheldon
Isaac Newton[2]	2006	Isaac Newton[3]	Philip Steele	Stock pictures
Josephine: The dazzling life of Josephine Baker[1]	2014	Josephine Baker[4]	Patricia Hruby Powell	Christian Robinson
Life in the ocean: The story of oceanographer Sylvia Earle[2]	2012	Sylvia Earle[3]	Claire A. Nivola	Claire A. Nivola
Little Melba and her big trombone[1]	2014	Melba Doretta Liston[4]	Katheryn Russell-Brown	Frank Morrison
Mack made movies[1]	2003	Mack Sennet[3]	Don Brown	Don Brown
Mae among the stars[2]	2018	Mae Jemison[3]	Roda Ahmed	Stasia Burrington
Malala: Activist for girls' e ducation[1]	2017	Malala Yousafzai[4]	Raphaelle Frier	Aurelia Fronty
Mama Africa! How Miriam Makeba spread hope with her song[1]	2017	Miriam Makeba[4]	Kathryn Erskine	Charly Palmer
Margaret and the moon[2]	2017	Margaret Hamilton[3]	Dean Robbins	Lucy Knisley
Marie Curie[2]	2018	Marie Curie[3]	Demi	Demi
Marie Curie: A brilliant life[2]	2004	Marie Curie[3]	Elizabeth MacLeod	Stock pictures

Martin's big words[1]	2001	Martin Luther King[4]	Doreen Rappaport	Bryan Collier
Me Jane[2]	2011	Jane Goodall[3]	Patrick McDonnell	Patrick McDonnell
My journey to the stars[2]	2017	Scott Kelly[3]	Scott Kelly	Andre Ceolin
Nelson Mandela[1]	2013	Nelson Mandela[4]	Kadir Nelson	Kadir Nelson
Neo Leo: The ageless ideas of Leonardo da Vinci[2]	2009	Leonardo da Vinci[3]	Gene Barretta	Gene Barretta
Newton's rainbow[2]	2017	Isaac Newton[3]	Kathryn Lasky	Kevin Hawkes
Night flight: Amelia Earhart crosses the Atlantic[1]	2011	Amelia Earhart[4]	Robert Burleigh	Wendell Minor
Nothing stopped Sophie The story of unshakable mathematician Sophie Germain[2]	2018	Sophie Germaine[3]	Cheryl Bardoe	Barbara McClintock
Odd boy out: Young Albert Einstein[1]	2004	Albert Einstein[3]	Don Brown	Don Brown
On a beam of light: A story of Albert Einstein[1]	2013	Albert Einstein[3]	Jennifer Berne	Vladimir Radunsky
Out of school and into nature[2]	2017	Anna Comstock[3]	Suzanne Slade	Jessica Lanan
Planting the trees of Kenya: The story of Wangari Maathai[1,2]	2008	Wangari Maathai[3]	Claire A. Nivola	Claire A. Nivola
Preaching to the chickens: The story of young John Lewis[1]	2016	John Lewis[4]	Jabari Asim	E.B. Lewis
Rachel Carson and her Book that changed the world[2]	2012	Rachel Carson[3]	Laurie Lawlor	Laura Beingessner
Rachel: The story of Rachel Carson[2]	2003	Rachel Carson[3]	Amy Ehrlich	Wendell Minor
Radiant child: The story of young artist Jean-Michel Basquiat[1]	2016	Jean-Michel Basquiat[4]	Javaka Steptoe	Javaka Steptoe
Rocks in his head[2]	2001	Leo Derwood Otis[3]	Carol Otis Hurst	James Stevenson
Rosa[1]	2005	Rosa Parks[4]	Nikki Giovanni	Bryan Collier
Saladin: Nobel prince of Islam[1]	2012	Saladin[4]	Diane Stanley	Diane Stanley
Schomburg: The man who built a library[1]	2017	Arthur Schomburg[4]	Carole Boston Weatherford	Eric Velasquez
Sequoyah: The Cherokee man who gave his people writing[1]	2004	Sequoyah[4]	James Rumford	James Rumford
Shark Lady: The true story of how Eugenie Clark became the ocean's most fearless scientist[2]	2017	Eugenie Clark[3]	Jess Keating	Marta Alvarez Miguens
Small wonders: Jean-Henri Fabre & his world of insects[2]	2015	Jean-Henri Fabre[3]	Matthew Clark Smith	Giuliano Ferri
Solving the puzzle under the sea: Marie Tharp Maps the ocean floor[2]	2016	Marie Tharp Maps[3]	Robert Burleigh	Raul Colon
Spring after spring: How Rachel Carson inspired the environmental movement[2]	2018	Rachel Carson[3]	Stephanie Roth Sisson	Stephanie Roth Sisson
Star stuff: Carl Sagan and the mysteries of the cosmos[1,2]	2014	Carl Sagan[3]	Stephanie Roth Sisson	Stephanie Roth Sisson
Starstruck: The cosmic journey of Neil deGrasse Tyson[2]	2018	Neil DeGrasse Tyson[3]	Kathleen Krull and Paul Brewer	Frank Morrison
Step right up: How Doc and Jim Key taught the world about kindness[1]	2016	Dr William Key[4]	Donna Janell Bowman	Daniel Minter
Strange fruit: Billie Holiday and the power of a protest song[1]	2017	Billie Holiday[4]	Gary Golio	Charlotte Riley-Webb
Swan: The life and dance of Anna Pavlova[1]	2015	Anna Pavlova[4]	Laurel Snyder	Julie Morstad

Talkin' about Bessie: The story of aviator Elizabeth Coleman[1]	2002	Elizabeth Coleman[4]	Nikki Grimes	E.B. Lewis
The boy who drew birds: A story of John James Audubon[2]	2004	John James Audobon[3]	Jacqueline Davies	Melissa Sweet
The boy who harnessed the wind[2]	2012	William Kamkwamba[3]	William Kamkwamba and Bryan Mealer	Elizabeth Zunon
The boy who invented TV: The story of Philo Farnsworth[2]	2009	Philo Farnsworth[3]	Kathleen Krull	Greg Couch
The boy who loved math: The improbable life of Paul Erdös[1]	2013	Paul Erdos[3]	Deborah Heiligman	LeUyen Pham
The brilliant deep: Rebuilding the world's coral reefs[2]	2018	Ken Nedymyer[3]	Kate Messner	Matthew Forsythe
The cat with the yellow star: Coming of age in Terezin[1]	2006	Ela Weissberger[4]	Susan Goldman Rubin and Ela Weissberger	Stock Pictures
The fantastic Ferris Wheel: The story of inventor George Ferris[2]	2015	George Ferris[3]	Betsy Harvey Kraft	Steven Salerno
The fantastic undersea life of Jacques Cousteau[2]	2009	Jacques Cousteau[3]	Dan Yaccarino	Stock pictures
The girl who thought in pictures: The story of Temple Grandin[2]	2017	Dr Temple Grandin[3]	Julia Finley Mosca	Daniel Rieley
The girl with a mind for math: The story of Raye Montague[2]	2018	Raye Montague[3]	Julia Finley Mosca	Daniel Rieley
The house Baba built: An artist's childhood in China[1]	2011	Ed Young[4]	Ed Young	Ed Young
The iridescence of birds: A book about Henri Matisse[1]	2014	Henri Matisse[4]	Patricia MacLachlan	Hadley Hooper
The man who made time travel[1,2]	2013	John Harrison[3]	Kathryn Lasky	Kevin Hawkes
The noisy paint box: The colors and sounds of Kandinsky's abstract art[1]	2014	Wassily Kandinsky[4]	Barb Rosenstock	Mary GrandPre
The right word: Roget and his thesaurus[1]	2014	Peter Roget[4]	Jen Bryant	Melissa Sweet
The storyteller's candle[1]	2008	Pura Belpré[4]	Lucia M. Gonzalez	Lulu Delacre
The tree of life[1,2]	2003	Charles Darwin[3]	Peter Sis	Peter Sis
The watcher: Jane Goodall's life with the chimps[1,2]	2011	Jane Goodall[3]	Jeanette Winter	Jeanette Winter
Toulouse Lautrec: The Moulin Rouge and the city of lights[1]	2005	Henri de Toulouse-Lautrec[4]	Robert Burleigh	Stock Pictures
Travelling man: The journey of Ibn Battuta[1]	2001	Ibn Battuta[4]	James Rumford	James Rumford
Tricky Vic: The impossibly true story of the man who sold the Eiffel Tower[1]	2015	Victor Lustig[4]	Greg Pizzoli	Greg Pizzoli
Trombone Shorty[1]	2015	Troy Andrews[4]	Troy Andrews	Bryan Collier
Trudy's big swim: How Gertrude Ederle swam the English Channel and took the world by storm[1]	2017	Gertrude Ederle[4]	Sue Macy	Matt Collins
Up & down: The adventures of John Jeffries, first American to fly[2]	2018	John Jeffries[3]	Don Brown	Don Brown
Voice of freedom: Fannie Lou Hamer, spirit of the civil rights movement[1]	2015	Fannie Lou Hammer[4]	Carole Boston Weatherford	Ekua Holmes
Walt Whitman: Words for America[1]	2004	Walt Whitman[4]	Barbara, Kerley	Brian Seznick
Wanda Gag: The girl who lived to draw[1]	2008	Wanda Gag[4]	Deborah Kogan Ray	Deborah Kogan Ray
Wangari's trees of peace[2]	2008	Wangari Maathai[3]	Jeanette Winter	Jeanette Winter

What to do about Alice? How Alice Roosevelt broke the rules, charmed the world, and drove her father Teddy crazy![1]	2008	Alice Roosevelt[4]	Barbara, Kerley	Edwin Fotheringham
When sparks fly: The true story of Robert Goddard, the father of US rocketry[2]	2018	Robert Goddard[3]	Kristen Fulton	Diego Funck
When the beat was born: DJ Kool Herc and the creation of hip hop[1]	2013	DJ Kool Herc[4]	Laban Carrick Hill	Theodore Taylor, III
Who says women can't be doctors?: The story of Elizabeth Blackwell[2]	2013	Elizabeth Blackwell[3]	Tanya Lee Stone	Marjorie Priceman
Whoosh! Lonnie Johnson's super soaking stream of inventions[2]	2016	Lonnie Johnson[3]	Chris Barton	Don Tate

[1] Recipient of the Notable Children’s Books (NCB) award.
[2] Recipient of the Outstanding Science Trade Book for Children (OSTB) award.
[3] Biographies of scientists.
[4] Biographies of non-scientists.

Appendix B – Codebook 1: Facial expression of awe in picture book biographies

Book Title: On its corresponding column in the supplementary spreadsheet, please enter the book title.

Biography of: On its corresponding column in the supplementary spreadsheet, please enter the name of the main character.

Page #: On its corresponding column in the supplementary spreadsheet, please enter the page number.

Date: Fill in the date when the coding form was completed, in the following format: dd/mm/yy

Below you will find the questions and how to answer these. Please fill the corresponding columns in the supplementary spreadsheet for each of the questions. Please look at each individual page of the picture book and evaluate the following characteristics. This includes all the pages between and including the front and back covers.

a) **Faces:** In the corresponding column, please enter the number of faces on each page.

*A face should have at least eyes and mouth.
*If there are more than five (5) faces on the page, please write down the number five (5) and stop counting.

b) **Awe facial expressions:** In the corresponding column, please enter the number of faces with the stereotypical awe expression on each page.

*The stereotypical representation of awe includes raised inner eyebrows, widened eyes, and an open drop-jawed mouth.
*If the faces don't include eyebrows, the stereotypical representation of awe can include only widened eyes and an open mouth.
*If the author draws all eyes as dots, all mouths closed, or some other regularity in all the faces throughout the book, the face should have at least one of the three main characteristics to count as awe.
*Some faces with a similar expression correspond to singing, shouting, or another activity. Use contextual cues to determine whether the image corresponds to an awe expression.

Appendix C – Dictionary 1: Expert-based dictionary for 'awe' based on the Oxford English dictionary

awe
awe-inspiring
awe-stricken
awe-struck
awed
awes
awesome
awestricken
awestruck
wonder
wondered
wonderful
wondering
wonders

Appendix D – Dictionary 2: Words related to 'awe' according to the taxonomy of emotions in Storm and Storm (1987)

amazement
astonished
awe
dazed
dazzled
disbelief
disconcerted
dumbfounded
incredulity
skeptical
startled
stunned
unnerved
wonder

Appendix E – Dictionary 3: University of South Florida word association norms for ‘awe’ (Nelson et al., 2004)

amaze
awesome
struck
shock
wow
surprise
wonder
admire
dumbfounded
impressed
stunned
unbelievable
inspire
like
beautiful
cool
dismay
excitement
happy
scared
awe

Appendix F – Dictionary 4: Small World of Words' norms for 'awe' (De Deyne et al., 2019)

admiration	gaze	sky
adorable	glory	some
agape	god	speechless
amaze	grandeur	struck
amazement	great	stun
amazing	impress	stunned
astonish	impressed	stunning
astonishing	impressive	surprise
astonishment	incredible	surprised
astound	inspiration	wonder
astounding	inspire	wonderful
awesome	inspired	wondering
awful	inspiring	wonderment
beautiful	kitten	wondrous
beauty	love	wow
big	majesty	awe
breathless	marvelous	
childlike	mesmerize	
cute	nature	
dazed	overwhelm	
dazzle	overwhelming	
disbelief	rapture	
disbelieve	respect	
entranced	revered	
fascinate	saw	
fascinating	shock	
fear	shock	
gaping	shocked	
gasp	shocking	

Appendix G – Dictionary 5: Fifty smallest Euclidean distances to 'awe' using the Global Vectors for Word Representation (GLOVE) algorithm (Pennington et al., 2014)

admiration
admire
admiring
afar
amaze
amazed
amazement
amused
astonished
astonishment
astounded
awe
awed
awe-inspiring
awestruck
captivated
curiosity
delight
disbelief
dismay
dumbfounded
ecstatic
enthralled
entranced
excitement
fascinated
fascination
glimpse
imagine
immense
incredible
joy
magnificence
marveled
marveling
marvelous
mesmerized
overjoyed
pity
reverence
seeing
shocked
sight
speechless
stunned
stupendous
surprise
wonder
wonderment
wonders
wondrous

Appendix H – Codebook 2: Elements of the situation of awe in picture book biographies

Book Title: On its corresponding column in the supplementary spreadsheet, please enter the book title.
Biography of: On its corresponding column in the supplementary spreadsheet, please enter the name of the main character.
Visual Unit #: On its corresponding column in the supplementary spreadsheet, please enter the visual unit number.
Date: Fill in the date when the coding form was completed, in the following format: dd/mm/yy

Please fill in the corresponding columns in the supplementary spreadsheet for each of the questions. Please look at each individual visual unit and evaluate the following characteristics.

a) **Attention Foci:** In the corresponding column, please enter the number corresponding to the type of agent, object, or action that is the focus of attention in the situation:
    1. Accomplishment
    2. Human-made artefact
    3. Natural object
    4. Non-human living organism
    5. Person
    6. Other
    99. Unable to determine

b) **Social context:** In the corresponding column, please enter the number corresponding to the number of people present in the situation.
    1. One (alone)
    2. Two (dyad)
    3. Less than five (small group)
    4. Five or more (crowd)
    99. Unable to determine

c) **Setting:** In the corresponding column, please enter the number corresponding to the place where the situation occurs.
    1. Natural (wilderness area, no human presence)
    2. Modified (natural area that has been transformed such as rural farmland or gardens)
    3. Built outdoors (outside settings that have been completely built such as cities and suburbs)
    4. Built indoors (indoor settings that have been completely built such as rooms and halls)
    5. Other

99. Unable to determine

d) **Event:** In the corresponding column, please enter the number corresponding to the background event occurring in such a situation.
   1. Arts, culture and entertainment
   2. Business and trade
   3. Private events
   4. Public and political
   5. Scientific and educational
   6. Sports and recreation
   7. Other
   99. Unable to determine

e) **Outcome:** In the corresponding column, please enter the number corresponding to the outcome of the situation.
   1. Admiration (e.g., object or person)
   2. Entertainment
   3. Learning
   4. Motivation (e.g., curiosity)
   5. Inspiration (e.g., deciding on a career)
   6. Shock
   7. Other
   99. Unable to determine

Appendix I – Codebook 3: Characteristics of the individual experiencing awe in picture book biographies

Book Title: On its corresponding column in the supplementary spreadsheet, please the book title.
Biography of: On its corresponding column in the supplementary spreadsheet, please enter the name of the main character.
Individual #: On its corresponding column in the supplementary spreadsheet, please enter the visual unit number.
Date: Fill in the date when the coding form was completed, in the following format: dd/mm/yy

Please fill the corresponding columns in the supplementary spreadsheet for each of the questions. Please look at each individual and evaluate the following characteristics.

a) **Action - Looking direction:** In the corresponding column, please enter the number corresponding to the direction the individual is looking to:
    1. Across
    2. Down
    3. Up
    99. Unable to determine

b) **Action - Direction of movement:** In the corresponding column, please enter the number corresponding to the direction of movement of the individual.
    1. Towards the object or person
    2. Not moving
    3. Moving away from the object or person
    99. Unable to determine

c) **Action - Communication:** In the corresponding column, please enter the number corresponding to the communicative expression performed by the individual.
    1. Clapping
    2. Communicating verbally
    3. Covering mouth
    4. Pointing
    5. Writing
    6. Other
    7. None
    99. Unable to determine

d) **Age:** In the corresponding column, please enter the number corresponding to the apparent age of the individual.

1. Baby
2. Child
3. Adult

99. Unable to determine

e) **Gender:** In the corresponding column, please enter the number corresponding to the apparent gender of the individual.
    1. Male
    2. Female
    3. Other

    99. Unable to determine

f) **Ethnicity:** In the corresponding column, please enter the number corresponding to the apparent ethnicity of the individual.
    1. African American or Black
    2. American Indian, Alaska Native, or Native American
    3. East or Southeast Asian
    4. Hispanic/Latinx
    5. Middle Eastern/Arab
    6. White
    7. Other

    99. Unable to determine

g) **Protagonist:** In the corresponding column, please enter the number corresponding to whether the individual is the main protagonist of the book.
    1. Yes
    2. No

    99. Unable to determine

Appendix J – Information sheet and consent form 1: Word association task

Assessing word associations in people from different backgrounds
INFORMATION SHEET FOR PARTICIPANTS

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide not to take part, there will be no disadvantage to you, and we thank you for considering our request.

What is the Aim of the Project?
The purpose of this project is to observe how people from different backgrounds make word associations. This project is being undertaken as part of the requirements of Daniel Silva's PhD research at the University of Otago in New Zealand.

What Types of Participants are being sought?
To participate in this study, you must:
1. Be over the age of 18.
2. Be a US resident
3. Speak English as your first language.
4. Use a desktop or laptop. Please don't use cell phones, mobiles, or tablets.
5. Not have taken this survey before.

Participants will be recruited through the online survey distributor Mechanical Turk. Participants will receive $1.50USD in Amazon Mechanical Turk credit for completed participation.

What will Participants be asked to do?

Should you agree to take part in this project, you will be asked to:

1. Read and sign a consent form.

2. Perform a continued word association task. In this task, you will receive a cue word. You will then have sixty (60) seconds to write down as many associates that come to mind for the given cue word.

3. Complete an online survey about your personal background. This includes demographic information such as age, ethnicity, gender, level of education, religious affiliation, and political orientation.

4. You will be debriefed once you have completed the task and the survey.

In total, this should take you between 8 -12 minutes. You will be free to exit this study at any time, though only completed surveys will receive compensation.

What Data or Information will be collected and what use will be made of it?

The raw data collected in this study includes:

1. Your word associations.
2. Your responses to the survey. This includes your demographic information such as age, ethnicity, gender, level of education, religious affiliation, and political orientation.

The personal data collected in this study includes:

1. Your email address (if provided).

All of the data is securely stored in two password-protected hard-drives kept under lock in the investigator's office. Only the two researchers, Daniel Silva and Jesse Bering will have access to all of the data. Two independent coders will have access to the word association data, but this data will not be linked to you in any way. The raw data (not your personal data) may be publicly archived.

Your personal information (i.e., emails) will be destroyed at the completion of Daniel Silva's PhD research project. The raw data will be retained for at least 5 years in secure storage, or possibly indefinitely. The raw data will be kept following the University's standards.

The raw data of this study may be made publicly available in a journal or a conference. It may also be part of a PhD thesis which will be kept in the University of Otago Library (Dunedin, New Zealand). In all cases every attempt will be made to preserve your anonymity.

Data collected for this study will not be put to commercial use.
You may withdraw your data from the project at any time and without any disadvantage to yourself of any kind.

If you have any questions about our project, either now or in the future, please feel free to contact either:

Daniel Silva Luna	and	*Jesse Bering*
University of Otago		University of Otago
+64 3 471 6147		+64 3 471 6147
daniel.silva@postgrad.otago.ac.nz		jesse.bering@otago.ac.nz

This study has been approved by the Department stated above. However, if you have any concerns about the ethical conduct of the research you may contact the University of Otago Human Ethics Committee through the Human Ethics Committee Administrator (ph +643 479 8256 or email gary.witte@otago.ac.nz). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

UNIVERSITY of OTAGO

Te Whare Wānanga o Otāgo
NEW ZEALAND

Assessing word associations in people from different backgrounds

CONSENT FORM FOR

PARTICIPANTS

I have read the Information Sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:

1. My participation in the project is entirely voluntary;

2. I am free to withdraw my data from the project at any time without any disadvantage;

3. Personal identifying information will be destroyed at the conclusion of the project. However, the raw data from this project may be publicly archived so that it may be used by other researchers. All information that could identify me will be removed or changed.

4. I will receive $1.50USD for completing the task and the survey.

5. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve my anonymity.

I agree to take part in this project.

....

(Signature of participant) (Date)

....

(Printed Name)

Appendix K – Instructions 1: Word association task

On the next screen begins a word association task.

In the task, a cue word will appear at the top of the screen. In the text boxes provided, we would like you to type the words that come to mind when you think of this word. Please do this as the words come to mind and only type words that are associated with the cue word.

For example, if you receive the cue word 'dog', you might think of the word associates – pet, cat, bog, Lassie, in the park, happy, bark, has fur, runs, animal, etc...– which you would type into the text boxes as they come to mind.

There are no right or wrong answers.

You will have 60 seconds to provide as many responses as you can for each cue word, after which the survey will continue automatically to the next word. The task will take between 3 and 5 minutes.

You can start typing right away.

Please press next to begin the task.

Appendix L – Short survey instrument of attitudes toward science (Füchslin et al. 2018)

1. How much do you agree with the following statement: Science plays an important role in my life. (1= "strongly disagree" ... 5= "strongly agree")
2. How much do you agree with the following statement: I specifically search for information about science. (1= "strongly disagree" ... 5= "strongly agree")
3. How much do you agree with the following statement: It is important to be informed about science. (1= "strongly disagree" ... 5= "strongly agree")
4. How interested are you in science? (1= "a great deal" ... 5= "not at all") (inverted)
5. How much do you agree with the following statement: Scientific research should be publicly funded. (1= "strongly disagree" ... 5= "strongly agree")
6. How much do you agree with the following statement: Science and research make our lives better. (1= "strongly disagree" ... 5= "strongly agree")
7. How much do you agree with the following statement: I would like to partake in scientific research once. (1= "strongly disagree" ... 5= "strongly agree")
8. How much do you trust science in general? (1= "a great deal" ... 5= "not at all") (inverted scale)
9. How much do you agree with the following statement: Science should have no limits to what it is able to investigate. (1= "strongly disagree" ... 5= "strongly agree")
10. How much do you agree with the following statement: Science can sort out any problem. (1= "strongly disagree" ... 5= "strongly agree")

Appendix M – Consumption of science communication scale

How often do you do one of the following ... (1= "never" ... 5= "very often")?

1. Watch science documentaries on television, streaming, or at the cinema
2. Listen to science radio or podcast
3. Read about science on daily/weekly print newspapers or magazines
4. Read about science in online newspapers, online magazines, or science websites
5. Visit institutional science websites (e.g., government, organizations)
6. Read about science on social media (e.g., Facebook, Twitter)
7. Read Wikipedia science articles
8. Visit science museums or exhibitions covering science
9. Attend events, talks, or discussions concerning science
10. Read or listen to non-fiction books on science
11. Talk about science with family, friends, or acquaintances

Appendix N – Spirituality and religiosity items

1. How religious are you? (1 = "not at all religious" … 5 = "very religious")
2. How spiritual are you? (1 = "not at all spiritual" … 5 = "very spiritual")

Appendix O – Demographic questionnaire

1. With what gender do you identify yourself?
    a. Male
    b. Female
    c. Other
2. Please write down your age.
3. Which of the following describes your ethnic background?
    a. African American or Black
    b. American Indian, Alaska Native, or Native American
    c. East Asian (e.g., Chinese, Japanese, etc)
    d. Hispanic/Latinx
    e. Middle Eastern
    f. Native Hawaiian or Pacific Islander
    g. Southeast Asian (e.g., Vietnamese, Cambodian, etc)
    h. South Asian (East Indian, Sri Lankan, etc)
    i. West Asian (Pakistani, Iranian, etc)
    j. White/European American
    k. Other
4. What is the highest level of education you have completed?
    a. Some high school
    b. High school diploma or equivalent
    c. Some college
    d. Bachelor's degree or equivalent
    e. Master's degree or equivalent
    f. Doctoral or professional degree
5. What is your political orientation? (1= "Very liberal", 4= "centre", 7= "Very conservative")
6. What is your religious affiliation?
    a. Wiccan or another Celtic, nature-based, or pagan religion
    b. Islam
    c. Hindu
    d. Buddhist
    e. Christian Protestant

f. Christian Catholic
g. Christian Other
h. Jewish
i. Agnostic
j. Atheist
k. Other

Appendix P – Constructing the Consumption of Science Communication Scale

Introduction

In modern capitalist societies, consumption is not just at the centre of the economic process, but it is linked to the acquisition of cultural capital, the constitution of identities, the formation of people's emotions, and the stratification of our societies, among other things (e.g., Illouz, 2009). The elusive role of consumption in our current understandings of the individual and society, however, shows how challenging it is to conceptualise academically (see Wherry & Woodward, 2019). Warde (2017) provides a simple definition by stating that consumption is the "process whereby agents engage in appropriation of a good, service, performance, information, or ambience, and which is a product of human work" (p. 66). Although quite broad, this definition captures the active role of the agent, the behavioural aspect of consumption, its social character, and the importance of learning information.

Various surveys and studies have tried to measure people's science communication-related consumption (e.g., Archer et al., 2015; Eurobarometer, 2010, Pew Research Center, 2017, Schäfer et al., 2018). These include forms of engagement associated with traditional mass media (e.g., BBVA Foundation, 2011), online resources (e.g., Schäfer & Taddicken, 2015), social media (e.g., Pew Research Center, 2017), visiting activities (e.g., Archer et al., 2015; Pew Research Center, 2017; Schafer et al., 2018), and talking to others about science (e.g., BBVA, 2011). While these studies have used questionnaires to compare people's use of different sources of information (Pew Research Center, 2017), to describe segmented populations (Schäfer et al., 2018), or as items in the development of scales (e.g., Archer et al., 2015), no scale exists on the consumption of science communication specifically. Thus, the following section presents the development and validation of such a scale.

Method

Item Pool

For the present research purposes, the consumption of science communication was defined "as agents engaging in the appropriation of goods, services, performance, information, or ambience, produced in the culture of science communication" (modified from Warde, 2017). The selected item pool comes from a review of previous studies that have measured people's consumption activities (e.g., Archer et al., 2015; Eurobarometer, 2010; Pew Research Center, 2017; Schäfer et al., 2018). The surveys reviewed, however, mostly converged around the same set of questions. Schäfer et al., (2018) had done a similar review exercise and, as such, most items were taken from their work. The items were reviewed by two experts in science communication and then discussed with colleagues. Moreover, three native English speakers from the United States reviewed the items for clarity of language. The following final list comprises fourteen Likert-type items presented in an end-defined format (i.e., only the end points are shown; see Dixon et al., 1984), where (1) is “never” and (5) is “very often”:

1. cons1 - Watch science documentaries on television, streaming, or at the cinema
2. cons2 - Listen to science radio or podcast
3. cons3 - Read about science on daily/weekly print newspapers or magazines
4. cons4 - Read about science in online newspapers, online magazines, or science websites
5. cons5 - Read science magazines
6. cons6 - Visit institutional science websites (e.g., government, organizations)
7. cons7 - Read about science on social media (e.g., Facebook, Twitter)
8. cons8 - Read Wikipedia science articles
9. cons9 - Watch science videos on YouTube or similar video platforms
10. cons10 - Visit science museums or exhibitions covering science
11. cons11 - Visit zoos, aquariums, or botanical gardens
12. cons12 - Attend events, talks, or discussions concerning science
13. cons13 - Read or listen to non-fiction books on science
14. cons14 - Talk about science with family, friends, or acquaintances

Participants

Three hundred and fifty-four participants were recruited via Amazon MTurk and were paid 0.50USD cents for their participation. I chose this number of participants based on having more than the 20:1 rule of thumb in the participant to item ratio, frequently used in scale development (Carpenter, 2018). Fifteen participants who answered extraordinarily fast (fastest 5% of survey completion time) were removed from the sample. This is a relatively effective way to control for low-quality data such as inattentive responses (see Leiner, 2019). Although there are no agreed-upon benchmarks on how to set temporal cutoffs (Matjašič et al., 2018), removals based on percentiles have been used successfully in previous research (e.g., Harms et al., 2017). One further participant was removed for failing to answer an honesty question. The final number of total participants was therefore 338.

Procedure

The survey was prepared on Qualtrics (Qualtrics, 2019) and posted through Turkprime/Cloudresearch (Litman et al., 2017) to MTurk. The study received approval from the Human Ethics Committee of the University of Otago as an extension of Category B proposal #D20/152 (Appendix S). Participants were asked to provide informed consent (Appendix AD) and were then given the following instructions:

> "On the next screens, you will be asked some questions about yourself. Please respond to the following questions as truthfully and accurately as you can. Remember that all your responses are completely anonymous. Press next to begin the survey."

Each of the statements was presented individually (one item on screen at a time) and in a randomized order. After completing the consumption of science communication items, the participants were presented with a ten-item short instrument measuring perceptions of science (Füchslin et al., 2018). Next, they answered two questions about their level of spirituality and religiosity, and this was followed by a demographic survey. Finally, participants received an honesty question and were briefly debriefed about the purpose of the survey.

Results

The Cronbach alpha for the 14 items was .901. Kaiser-Meyer-Olkin measure of sampling adequacy KMO = 0.919 suggests that the 14 items can be used in factor analysis (≥ .60) (Carpenter, 2018). Similarly, Bartlett's test of Sphericity was significant (χ^2(2039.02, 91), $p <$ 0.001). Common factor analysis following principal axis factoring was used to evaluate the dimensionality of the scale. This method is preferred over maximum likelihood when there are deviations from normality (Carpenter, 2018).

Considering the focus on the behavioural aspect of consumption, I expected the construct to have one dimension. The scree plot suggests a one-factor solution (Figure M.1). The loadings matrix of principal axis factoring (Table M.1) shows all factor loadings are higher than 4, which is above the .32 suggested for retaining the items (Carpenter, 2018). 'Visit zoos, aquariums, or botanical gardens' had the lowest loading, possibly due to being qualitatively different to all the other items in the questionnaire, as it describes activities that are done with children as part of a family, group, or school visits to these places (Schwan et al., 2014). In other words, the motivational structure and cultural mores surrounding the participation in these activities may be different from those of the other items in the questionnaire. Given these considerations, this item was removed from the scale.

Figure M.1

Scree Plot

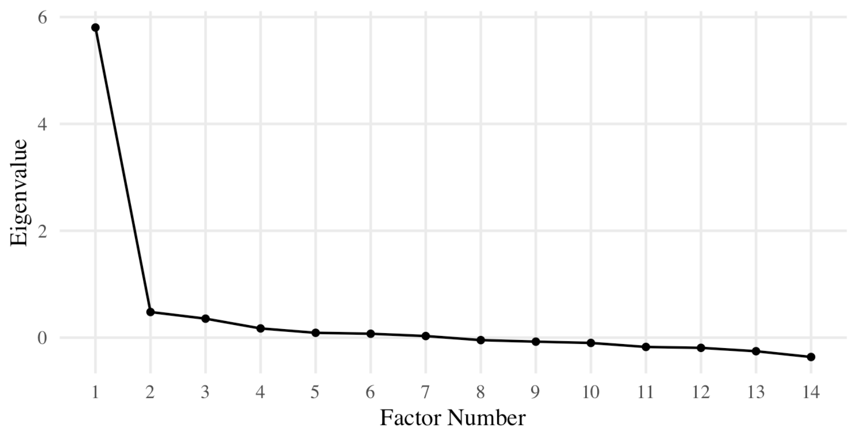

Table M.1

Consumption of science communication item loadings (n = 338)

Item	Component
Cons5	0.77
Cons6	0.73
Cons13	0.72
Cons4	0.68
Cons3	**0.67**
Cons1	0.65
Cons14	0.64
Cons12	0.63
Cons2	0.62
Cons10	0.61
Cons9	0.61
Cons8	0.6
Cons7	0.57
Cons11	0.45

Notes: The extraction method was principal axis factoring (Costello & Osborne, 2005). The eleven items selected for the final scale are in bold.

Confirmatory factor analysis (CFA) for the same sample using the ‘lavaan’ R package (Rosseel, 2012), however, suggested that a one-factor model with thirteen had a relatively poor fit (χ^2 (65) = 204.5014; p < .001; RMSEA = 0.08; CFI = .924, TLI = .908), with two out of the four main observed indicators within the acceptable thresholds suggested in the literature (e.g., Browne & Cudeck, 1992). High modification indices indicated potential item redundancies that might be addressed to increase the model's fit. This was particularly true with items one (cons1) and nine (cons9) (MI = 21.22) on the one hand, and items three (cons3) and five (cons5) (MI = 20.10), on the other. Upon closer inspection, the wording of item one (1) has the word 'streaming', which can be interpreted as including 'watching science videos on YouTube or similar platforms'. In that sense, question nine (cons9) may be somewhat redundant, as it is included within question one (cons1). A similar situation can be found with items three (cons3) and five (cons5), wherein 'print newspapers and magazines' might be interpreted as including 'science magazines'. Although it is tempting to add a path between these items in the model, I opted instead to increase the parsimony of the scale by removing these two possibly redundant items (Cons 5 and Cons9) (see Wieland et al., 2017). Removing items five and nine indeed improved the model's fit, albeit modestly (χ^2 (44) = 122.358; $p < .001$; RMSEA = 0.073; CFI = .943, TLI = .928).

Discussion

This section began with a proposal to develop a much-needed science communication consumption scale, one that measures consumption behaviour based on fourteen (14) items derived from a literature review. However, statistical considerations revealed that an 11-item scale is better suited to capture the key construct under consideration. In the next section, I provide evidence for the validity of this science communication scale through a CFA, using a new dataset and a comparison to other scales to test its convergent and divergent validity.

Appendix Q – Confirmatory factor analysis and convergent and divergent validity of the Consumption of Science Communication Scale

Introduction

To test the scale's internal structure captures, I collected a new data sample to perform a new confirmatory factor analysis (Furr, 2013). Furthermore, to validate the scale, I examined its relations to other individual difference measures and test for both convergent and divergent validity. As such, the participants in this new study responded to five other short scales, including an adapted version from the National Science Board Science Literacy Test (National Science Board, 2010), the Belief in Science Scale (BISS) (Farias et al., 2013), the Analysis subscale of the Oregon Vocational Interests Scale (Pozzebon et al., 2010), the Paranormal Short Inventory (Randall, 1997), and the Epworth Sleepiness Scale (Johns, 1991). These scales were chosen for their shortness, having been validated, and their use in other similar studies.

Method

Participants

Three hundred participants from the United States were recruited from Amazon MTurk for 1.00USD. Two participants were removed for failing an honesty question. As in the previous study, the fastest 5% of participants were removed based on their survey completion time to filter out some inattentive responses common in online surveys (Leiner, 2019). The final sample for analysis included two hundred and eighty-three participants (n = 283).

Materials

Consumption of Science Communication Scale

Participants responded to the eleven items of the Consumption of Science Communication Scale previously developed.

Oregon Vocational Scale - Analysis Subscale

This scale was developed to test different levels of interest in different vocations. Their analysis subscale captures people's interest in scientific vocations, asking participants whether they are interested in various scientific disciplines. This scale has been psychometrically tested (Pozzebon et al., 2013) and has been used to test the validity of attitudes towards science scales (e.g., Hartman et al., 2017). I predicted a positive correlation between this and the Consumption of Science Communication Scale.

Belief in Science scale

This recently validated scale captures people's belief in science (Dagnall et al., 2019), specifically, the "belief in the value of science as an institution and in its superiority as a source of knowledge" (Farias et al., 2013, p. 1211). I expected to observe a positive relationship between the Consumption of Science Communication Scale and the belief in science scale.

NSF Science Knowledge Survey

For over three decades, the National Science Foundation has commissioned a version of this true/false test to thousands of participants across the United States (see Stocklmayer & Bryant, 2012). The ten-question version of the survey adopted for the present study has been previously used (e.g., Takahashi & Tandoc, 2016). Six of the questions are true and four are false. I expected people with more consumption of science communication to score higher in this Science Knowledge Survey.

Paranormal Short Inventory

This 13-item scale is a simplified version of a longer inventory (Randall & Desrosiers, 1980) and captures a diversity of beliefs in the paranormal, including astrology, magic and precognition (Randall, 1993). Overall, I expected a negative relationship between scores on this measure and the Consumption of Science Communication Scale.

The Epworth Sleepiness Scale

This very simple 8-item scale is widely used to capture people's daytime sleepiness and has been psychometrically tested on multiple occasions (Johns, 1991, 1992). Overall, I expected to find no correlation between this and the Consumption of Science communication Scale.

Procedure

The study received approval from the Human Ethics Committee of the University of Otago as proposal #D20/294 (Appendix AE). Again, the survey was prepared on Qualtrics (Qualtrics, 2019) and posted through Turkprime/Cloudresearch (Litman et al., 2017) to MTurk.

Participants were first asked to provide informed consent (Appendix AF) and were then given the instructions. Each participant received the six scale items in randomized order, after which they received an honesty question. They were then debriefed and thanked for their participation. The data were analysed in R using the 'lavaan' package (Rosseel, 2012).

Results

Confirmatory factor analysis

The Cronbach alpha for the 11 items was 0.913. The indicators for the one-factor solution of the CFA showed a good fit (χ^2 (44) = 119.5014; $p < .001$; RMSEA = 0.078; CFI = .941, TLI = .926). Similarly, the standardized factor loading for the eleven items derived from the CFA using maximum likelihood estimation (Table N.1), are above the 0.5 recommended threshold and are significant (Hair et al., 2010), confirming that the items are a good fit for the latent factor.

Table N.1

Standardized factor loadings for CFA (n=283)

Item	Component
Read about science in online newspapers, online magazines, or science websites	0.781
Visit institutional science websites (e.g., government, organizations)	0.768
Read about science on daily/weekly print newspapers or magazines	0.703
Listen to science radio or podcast	0.694
Watch science documentaries on television, streaming, or at the cinema	0.685
Read or listen to non-fiction books on science	0.685
Talk about science with family, friends, or acquaintances	0.653
Attend events, talks, or discussions concerning science	0.647
Visit science museums or exhibitions covering science	0.574
Read Wikipedia science articles	0.570
Read about science on social media (e.g., Facebook, Twitter)	0.530

Note: Maximum likelihood estimation method was used

Convergent and divergent validity

I ran multiple simple linear regressions with the Consumption of Science Communication Scale as the dependent variable and each of the five measures as the independent variable in each test. I then revised for false discovery rates using the Benjamini-Hochberg correction (Benjamini & Hochberg, 1995). The results are presented in table N.2. As predicted, higher scores in the Consumption of Science Communication Scale were predicted by the three measures of interest, belief, and knowledge of science. Furthermore, there was no relationship between the Epworth Sleepiness Scale and the Consumption of Science Communication scale, as predicted. However, the expected negative relation between the

Consumption of Science Communication scale and the Paranormal Short Inventory was not significant, suggesting that engagement with science communication is found across people with diverse worldviews, including those who hold paranormal beliefs.

Table N.2
Simple linear regression – Consumption of science communication scale and the examined variables

Predictor	Cronbach Alpha	Expected relationship	Estimate	*SE*	*p (adjusted p)*
Oregon Vocational Scale - Analysis Subscale	0.898	Positive	0.433	0.040	0 (0)**
Belief in Science scale	0.945	Positive	0.144	0.036	0 (0)**
NSF Science Knowledge Survey	0.730	Positive	0.053	0.021	0.0101 (0.0168)*
Paranormal Short Inventory	0.880	Negative	0.002	0.049	0.963 (0.963)
The Epworth Sleepiness Scale	0.774	None	0.110	0.085	0.198 (0.247)

*$p < 0.05$, **$p < 0.01$.

Discussion

Overall, the findings from the present study serve to validate the Consumption of Science Communication Scale. The results of the CFA suggest a robust internal structure of the eleven items. Moreover, the results of the validity tests indicate a convergence with similar measures for interest in science, belief in science, and scientific knowledge. Although, as predicted, there was no relation of the construct to people's levels of daytime sleepiness, somewhat surprisingly there was also no ostensible connection to paranormal beliefs. One speculative interpretation of this latter finding is that many people interested in science may also be interested in ufology, ghost hunting, and other practices where the demarcation of pseudoscience and science is continuously being contested. Future work can reinforce these results through test-retest reliability measures and tests of its predictive validity.

Appendix R – Ethics approval 1: #D19/374

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND

D19/374

Academic Services
Manager, Academic Committees, Mr Gary Witte

13 December 2019

Dr J Bering
Centre for Science Communication
133 Union St East

Dear Dr Bering,

I am writing to confirm for you the status of your proposal entitled "**Assessing the mental representations of awe and wonder in science communication through a continued word association task.**", which was originally received on December 4, 2019. The Human Ethics Committee's reference number for this proposal is **D19/374**.

The above application was Category B and had therefore been considered within the Department or School. The outcome was subsequently reviewed by the University of Otago Human Ethics Committee. The outcome of that consideration was that the proposal was approved.

Approval is for up to three years from the date of HOD approval. If this project has not been completed within three years of this date, re-approval must be requested. If the nature, consent, location, procedures or personnel of your approved application change, please advise me in writing.

Yours sincerely,

Gary Witte

Mr Gary Witte
Manager, Academic Committees
Tel: 479 8256
Email: gary.witte@otago.ac.nz

Appendix S – Codebook 4: Property type categorization

Coder Name: Please indicate your name at the top box.
Date: Please fill in the date that the coding form was completed in the following format: dd/mm/yy.

Please code each of the cue-response pair with the numbers one (1) through six (6) using the following categories. Every word association pair should have only one code. Please choose the one you consider the most appropriate.

1. Lexical Feature: An associate that is based on a quick linguistic response to the emotion word.
   i. forward completion (e.g., fear→less)
   ii. backward completion (joy→kill)
   iii. part of a word (surprise→prize)
   iv. orthographic similarity (happy→nappy, happen, hazy), (fear →dear, year, feat)
   v. mediation (love→lovestruck→starstruck),
   vi. expression (happy → Larry, clam, don't worry, color)
   vii. meta-comment (love → one syllable word, fear→ Ahh; disgust → Ew)
2. Taxonomic Feature: An associate that is in the same or similar taxonomic category as the emotion word.
   i. Synonyms (e.g. happiness→joy, bliss, gladness)
   ii. Antonyms (e.g., love→hate, detestation, anger→delight, calmness)
   iii. Similar (not quite synonyms) (e.g., love→fondness, anger→envy, venom)
   iv. Ontological Category (e.g., happiness→ emotion, fear→response, disgust→feeling)
   v. Superordinate (e.g., happiness→ emotion)
   vi. Coordinate (e.g., happiness→fear, anger, disgust)
   vii. Subordinate (e.g., anger→passive, chronic, verbal
   viii. Individual (e.g., anger→road rage)
3. Entity Feature: An associate that indicates a concrete property of the emotion word. It can be a physical, metaphorical, or abstract, property of someone who is experiencing an emotion.
   i. Surface properties (e.g., anger → red face, happy→smile)

ii. Materials (e.g., love → crochet, love → butterflies)
iii. Behavior (e.g., anger →scream, happiness→laughter, disgust→move away from).
iv. Abstract property (e.g., love → selflessness, disgust → natural, joy→creativity)
v. Quantity (e.g., love → lots of, anger → brimming with).

4. Situational Feature: An associate that indicates a concrete feature of the external situation where the emotion word occurs including setting, agents and objects.
   i. Action (e.g., happiness → running, anger → flying)
   ii. Object (e.g., love → apple, happiness → clarinet)
   iii. Person (e.g., love → mother, anger → driver)
   iv. Living Thing (e.g., happiness → dog, anger → cat)
   v. Social Organization (e.g., disgust→ Congress, sadness→health insurance)
   vi. Building (e.g., happiness→stable, love → museum)
   vii. Location (e.g., love→Michigan, joy→forest0
   viii. Time (e.g., anger→morning, happiness → evenings)
   ix. Event (e.g., love →wedding, sadness→funeral)
   x. Manner (e.g., happiness → fast, sadness → long)
   xi. Physical state/property (e.g., happiness→fluffy, sadness→rainy).
   xii. Quantity (e.g., anger → many, happiness→ vast)
      i. Function (e.g., happiness→bonding, disgust→revulsion)
5. Introspective Feature: An associate that indicates an internal feature of the person experiencing an emotion. This includes feelings, thoughts, and evaluation.
   i. Affect (e.g., joy → positive, love→calm).
   ii. Abstract evaluation (e.g., joy → silly, anger→discouraging).
   iii. Cognitive state (e.g., joy → disbelief, love→appreciation).
   iv. Contingency (e.g., love→ requires dedication, happiness → because there was sunshine)
   v. Cognitive operation (e.g., love→fantasize, happiness→believe, joy→ appreciate).
   vi. Negation (e.g., anger → not good, love → doesn't expire).
6. Miscellanea: Please use this category if the associate doesn't fit in any other category.

99. Unable to determine

Appendix T – Ethics approval 2: #D20/152

D20/152

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND

Academic Services
Manager, Academic Committees, Mr Gary Witte

27 May 2020

Dr J Bering
Centre for Science Communication
133 Union St East

Dear Dr Bering,

I am writing to confirm for you the status of your proposal entitled "**Assessing people's mental representations of awe and perceptions of science through a word association task and survey.**", which was originally received on May 26, 2020. The Human Ethics Committee's reference number for this proposal is **D20/152**.

The above application was Category B and had therefore been considered within the Department or School. The outcome was subsequently reviewed by the University of Otago Human Ethics Committee. The outcome of that consideration was that the proposal was approved.

Approval is for up to three years from the date of HOD approval. If this project has not been completed within three years of this date, re-approval must be requested. If the nature, consent, location, procedures or personnel of your approved application change, please advise me in writing.

Yours sincerely,

Gary Witte

Mr Gary Witte
Manager, Academic Committees
Tel: 479 8256
Email: gary.witte@otago.ac.nz

Appendix U – Codebook 5: Natural kind responses

Coder Name: Please indicate your name at the top box.
Date: Please fill in the date that the coding form was completed in the following format: dd/mm/yy.

Please code the word responses as 1 = natural kind or 0 = other.

Natural kind words refers to objects "not constructed by humans" (Gelman, 1988, p. 69). This definition includes both living agents such as rabbits and roots, and non-living objects such as mountains and rocks.

Appendix V – Sample segmentation with Latent Class Analysis (LCA)

Traditional methods of segmenting a sample such as median split or extreme group approaches have been largely criticised in social sciences (Preacher et al., 2005). A case can be made for segmenting a sample applying taxometric methods when latent classes of individuals can be thought of as discrete categories (MacCallum et al., 2002). Multiple segmentation studies in science communication have observed considerable attitudinal, perceptual, behavioural, and demographic differences between the engaged and the disengaged (e.g., Maibach et al., 2011; Nisbet & Markowitz, 2014; Runge et al., 2018; Schäfer et al., 2018). These have used methods such as hierarchical clustering and principal components analysis to segment these groups (Nisbet & Markowitz, 2014; Runge et al., 2018). Other studies have used latent class analysis (LCA) (Maibach et al., 2011; Schäfer et al., 2018), a common technique used in post-hoc analysis of categorical and ordinal variables to describe "latent classes or "hidden groups," within a population (Nylund-Gibson & Choi, 2018).

Table U.1 shows the results of the first five cluster solutions using the eleven consumption of science communication items. The lowest value for both the Bayesian Information Criterion (BIC) and the model entropy suggest the three-cluster solution to be the best fit for the variables. The entropy value of 0.923 is considered to be a "good'' model for classifying cases (Nylund-Gibson & Choi, 2018). I used the R package 'poLCA' (Linzer & Lewis, 2011) to conduct the LCA. Following previous work on science communication which has observed categorical differences between the engaged and disengaged in this cultural space, I segmented the sample from study 1 (n = 259) into three groups using LCA: the engaged, the interested, and the disengaged.

Table U.1
Results of latent class analysis for one through five class solutions (N=259)

Number of Classes	log-likelihood	resid. df	BIC	cAIC	likelihood-ratio	Entropy
1	-4253.21	215	8750.92	8794.92	5630.76	-
2	-3865.79	170	8226.13	8315.13	4855.91	0.925
3	-3724.24	125	8193.1	8327.1	4572.82	0.923
4	-3665.41	80	8325.5	8504.5	4455.16	0.929
5	-3612.44	35	8469.62	8693.62	4349.22	0.931

Appendix W – Call for interviewees: Emotions in science communication

Hello Everyone,

My name is Daniel Silva and I'm a PhD student at the University of Otago conducting research on the uses and roles of emotion in science communication. As part of my PhD work, I'm looking for fifteen (15) practising science communicators for an hour-long Zoom interview about their ideas on emotion and experiences with these in their life and work.

If you practice science communication in English and are interested in participating, please email me at daniel.silva@postgrad.otago.ac.nz. I'd love to hear from you.

Participants will enter a raffle for a €150 gift certificate.

Thank you and hope you are all well and safe,
Daniel

Appendix X – Information sheet and consent form 2: Interviews

The Emotions of Science Communicators
INFORMATION SHEET FOR PARTICIPANTS

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate, we thank you. If you decide not to take part, there will be no disadvantage to you, and we thank you for considering our request.

What is the Aim of the Project?
The purpose of this project is to apprehend the science communicator's understanding of emotions, the use of awe in their work, and their experiences with this emotion.

What Types of Participants are being sought?
To participate in this study, you must:
1. Be over the age of 18;
2. Work as a science communicator;
3. Use English as your first language in your work;
4. Not have done this interview before.

Fifteen (15) interviewees will be recruited via forums. After the interview participants will enter a raffle for one €150 gift card.

What will Participants be asked to do?

Should you agree to take part in this project, you will be asked to

1. Read and sign a consent form.

2. Fill in a form with your personal and work details.

3. Complete a brief demographics survey.

4. Set a date and time for a Zoom/Skype interview via email with the researcher.

5. Complete an hour-long interview with the researcher via Zoom/Skype at a time of your convenience. You will be free to exit the interview at any time.

6. You will be debriefed at the end of the interview.

During the interview you will be asked to describe an emotional experience of awe and wonder. These are usually regarded as positive emotions, yet some people might find psychological discomfort while recollecting their personal emotional experiences. Please be aware that you may decide not to take part in the project without any disadvantage to yourself. You are also free to walk away from the interview at any point.

What Data or Information will be collected and what use will be made of it?
The data collected in this study includes:

3. Your personal and work data (e.g., name, email, profession, job title, location, company/institution)
4. Your demographic information (e.g., age, gender, ethnicity, first language)
5. Your interview responses.

The interview follows a semi-structured approach where the questions have been previously prepared and vetted by the ethics committee of the University of Otago. The Zoom/Skype interviews will be video recorded and transcribed by the researchers. All efforts will be made to remove or change any personal information that could identify you in these transcriptions. These transcriptions will be the raw data used in the analysis.
All of the data will be securely stored in two password-protected hard-drives kept under lock in the investigator's office. Only the two researchers, Daniel Silva and Jesse Bering will have access to all of the data. The raw data (not your personal data) may be publicly archived.

Your personal information will be destroyed at the completion of the research project. This includes the video recording and your personal and work data. The raw data (i.e., the anonymized transcriptions) will be retained for at least 5 years in secure storage, or possibly indefinitely. The raw data will be kept following the storage standards from the University of Otago.

The raw data of this study may be made publicly available in a journal or a conference as part of an article or a presentation. It may also be part of a PhD thesis which will be kept in the University of Otago Library (Dunedin, New Zealand). Every effort will be made to remove any information that could personally identify you in all published materials.

Data collected for this study will not be put to commercial use.

You may withdraw your data from the project at any time and without any disadvantage to yourself of any kind.

What if Participants have any Questions?
If you have any questions about our project, either now or in the future, please feel free to contact either:

Daniel Silva Luna	and	Associate Professor Dr. *Jesse Bering*
University of Otago		University of Otago
+64 3 471 6147		+64 3 471 6147
daniel.silva@postgrad.otago.ac.nz		jesse.bering@otago.ac.nz

This study has been approved by the Department stated above. However, if you have any concerns about the ethical conduct of the researcher you may contact the University of Otago Human Ethics Committee through the Human Ethics Committee Administrator (ph +643 479 8256 or email gary.witte@otago.ac.nz). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

The Emotions of Science Communicators
CONSENT FORM FOR PARTICIPANTS

I have read the Information Sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage. I know that:

1. My participation in the project is entirely voluntary;

2. I may withdraw my data from the project at any time without any disadvantage to myself of any kind.

3. Personal identifying information (i.e., *videos recording, personal and work data*) will be destroyed at the conclusion of the project but any raw data (i.e., the anonymized transcriptions), which results from the project, will be retained in secure storage for at least five years;

4. Every effort will be made to remove any information that could personally identify me in the raw data.

5. The raw data from this project may be shared so that it may be used by other researchers, but every effort will be made to remove or change the information that could identify me.

6. I will be talking about my own emotional experience during the interview. I might experience a little discomfort while reporting on these emotional experiences. I am free to withdraw from the interview at any point without any disadvantage to myself;

7. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve my anonymity.

8. My name will enter a raffle for a €150 gift card.

I agree to take part in this project.

....
(Signature of participant) (Date)

....
(Printed Name)

Appendix Y – Personal and work details questionnaire

1. Title:
2. Name:
3. Surname:
4. Current country of residence:
5. Current Job Title:
6. Brief Job Description:
7. What science topic do you cover the most in your work?
    a. Biological sciences
    b. Engineering and Technology
    c. Physical and chemical sciences
    d. Space sciences
    e. Medical and health sciences
    f. Earth sciences
    g. Environmental sciences
    h. Formal sciences
    i. Social sciences
    j. Other sciences

Appendix Z – Interview Questions

Thank you so much for your time talking with me. I'm doing my PhD research on the role of emotions and awe in science communication and your experience as a practitioner will definitively contribute to our understanding of how these are used and their roles in our field. I just want to remind you that there are no right or wrong answers.

Warm up

Perhaps you can start by telling me a bit about your work.

First, I would like to ask you about your overall thoughts on emotions.

1. How would you define the word 'emotion'?
2. Why do you think people have emotions?
3. How important do you consider emotions in the communication of science? Why?
4. How do you use emotions in your work as a science communicator?
    a. Is this explicit or implicit?
    b. What techniques or practices do you consider important to elicit emotions from your audience?
5. Which emotions do you consider important in science communication?

Now I would like to ask you about the emotion awe.

6. How often do you personally experience this emotion?
7. If you don't mind, could you think now of a memorable or recent 'awe' experience that you've had.
    a. What was the situation where this emotion occurred?
    b. What specifically caused this emotion? What words would you use to describe this?
    c. Where were you exactly? When was this?
    d. How did you feel? How did your body/mind feel during this experience?
    e. How did you express this emotion through your facial or bodily gestures? What actions did you perform? Did you say anything?
    f. What did you do afterwards? What was the result of having this experience with awe? Did the experience have any short or long-term consequences on you?

8. I would like to ask you more about this emotion, ‘awe’. How would you define this emotion?
9. What other emotions do you think are related to it?
10. What is the role of this emotion in the communication of science?
11. Do you use this emotion in your work? If so, how?
12. Would you say some particular branch of science is more given for this emotion than others?
13. What practices in science communication do you think get people to experience awe?
14. How much do you think science communicators incorporate emotions in their work?
15. Do you think there is a tension between science facts and emotional content?
16. To conclude, I’d like to ask you can you tell me about a recent or memorable work of science communication that you thought was awesome?
17. Is there something else you would like to add?

Thank you,

Appendix AA – Ethics approval 3: #D20/151

D20/151

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND

Academic Services
Manager, Academic Committees, Mr Gary Witte

27 May 2020

Dr J Bering
Centre for Science Communication
133 Union St East

Dear Dr Bering,

I am writing to confirm for you the status of your proposal entitled "**The Emotions of Science Communicators: Beliefs on emotions and awe experiences of science communicators.**", which was originally received on May 26, 2020. The Human Ethics Committee's reference number for this proposal is **D20/151**.

The above application was Category B and had therefore been considered within the Department or School. The outcome was subsequently reviewed by the University of Otago Human Ethics Committee. The outcome of that consideration was that the proposal was approved.

Approval is for up to three years from the date of HOD approval. If this project has not been completed within three years of this date, re-approval must be requested. If the nature, consent, location, procedures or personnel of your approved application change, please advise me in writing.

Yours sincerely,

Mr Gary Witte
Manager, Academic Committees
Tel: 479 8256
Email: gary.witte@otago.ac.nz

Appendix BB – Example of transcription excerpt

Name of the research project: Emotions in science communication

Speakers: Daniel Silva (DS), Interviewee 16 (Int16)

Date and time of the interview or recording of the event: 14 June 2020, 9pm

Audio file name or number: Int16.mp4

Duration of audio file: 00:31:30

DS

I want to start by asking you: how would you define the word emotion?

Int16

(laughs) (..) that's a good question. (..) I suppose emotions are feelings. So non-logical responses to the world around you (.) which, yeah, they don't necessarily come from the thought process but perhaps from the more direct experience of yourself with (.) stimuli, external stimuli.

DS

Why do you think people have emotions?

Int16

I love these questions. I don't know. I suppose I always thought of it as mind, body, and soul. So emotions are the soul part, so I suppose they are an inherent part of being human, but animals also feel emotions too so maybe it is an innate part of being alive.

DS

How important do you think emotions are for the communication of science?

Int16

(.) I think that (.) science communicators should have an element of emotion in what they deliver and how they speak about science. Scientist can rely a little more on, I suppose an objective presentation of facts, but for people to be able to connect to stories and connect the facts they need to feel so. I think it is important in science communication to have an element of emotion in your narratives.

DS

Could you perhaps elaborate a little bit more on that? What do you mean with narratives?

Int16

Well if you are say writing a story about an interesting piece of research, you can deliver all the facts you want, but that doesn't help people connect to either the people doing the research or the benefits of the research and make them feel good about what's being done or at least interested in it, you want to have that little 'wow' factor and the 'wow' factor always, well not always, but can be primarily driven by emotions.

DS

How do emotions show up in your work as a science communicator?

Int16

(.) When we work with our researchers we try and get them to say things that make them seem human which has those emotional elements of things, not just subscribe to what the research is but how it made them feel. Or what impressions it had upon them, so we try to pull up quotes from them. I suppose, like you are trying to do with me now. But highlight the human aspect of what you are doing (.) or else it will turn up very dry. So, usually it will work, sometimes in video, so we do some multimedia stuff as well, certain soundtracks, so if you select certain piece of music it can make people feel inspired or it can make them feel curious, or emotional, as well as the actual content, and the people you choose to put in your videos as well.

Appendix CC – Codebook 5: Elements of the awe situation

Coder Name: Please indicate your name at the top box.
Date: Please fill in the date that the coding form was completed in the following format: dd/mm/yy.

Each word or phrase refers to one element of the emotion situation. Please code each reference with the numbers one (1) through twelve (12) in the supplementary spreadsheet using the following categories. Every reference should have at least one code. Please choose the one you consider the most appropriate.

1. **Attention foci.** The agent, object, or action that is the focus of attention during the awe situation.
2. **Social context.** Other human agents present during the awe situation.
3. **Setting.** Description of the physical place where the awe situation occurs.
4. **Event.** Background event or actions in which the awe situation occurs.
5. **Appraisal/evaluation**. The evaluation of the agent, object, action, or situation that where awe is represented.
6. **Valence.** Whether an awe situation is described as positive or negative.
7. **Arousal.** Whether an awe situation is described as exiting or calming.
8. **Other emotions**. Other emotion categories used to describe awe.
9. **Motivations.** Motivations accompanying the awe situation.
10. **Bodily sensations.** Bodily sensations used to describe awe.
11. **Action.** Behaviour or expressions performed during an awe situation.
12. **Outcomes.** Results of the awe situation.
99. **Unable to determine**

Appendix DD – Information sheet and consent form 3: Consumption of science communication scale development

INFORMATION SHEET FOR PARTICIPANTS

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide not to take part, there will be no disadvantage to you, and we thank you for considering our request.

What is the Aim of the Project?
The purpose of this project is to validate an instrument on people's relationship to science.

What Types of Participants are being sought?
To participate in this study, you must:

6. Be over the age of 18.
7. Be a US resident
8. Not have taken this survey before.

Participants will receive $0.50USD for completed participation.

What will Participants be asked to do?
Should you agree to take part in this project, you will be asked to:

5. Read and sign a consent form.

6. Complete an online survey about your attitudes towards science, your consumption of science and your personal background. This includes demographic information such as age, ethnicity, gender, level of education, religious affiliation, and political orientation.

7. You will be debriefed once you have completed the task and the survey.

In total, this should take you between 3-5 minutes. You will be free to exit this study at any time, though only completed surveys will receive compensation.

What Data or Information will be collected and what use will be made of it?
The raw data collected in this study includes:

6. Your responses to the survey.

All of the data will be securely stored in two password-protected hard drives kept under lock in the investigator's office. Only the two researchers, Daniel Silva and Jesse Bering will have access to all of the data.

Your personal information will remain anonymous as an MTurk ID. This personal information will be destroyed at the completion of the research project. The raw data will be retained for at least 5 years in secure storage, or possibly indefinitely. The raw data will be kept following the storage standards from the University of Otago.

The raw data of this study (not your personal data) may be made publicly available in a journal or a conference. It may also be part of a PhD thesis which will be kept in the University of Otago Library (Dunedin, New Zealand).

Data collected for this study will not be put to commercial use.

You may withdraw your data from the project at any time and without any disadvantage to yourself of any kind.

If you have any questions about our project, either now or in the future, please feel free to contact either:

Daniel Silva Luna and Associate Professor Dr. Jesse Bering

Daniel Silva Luna	Associate Professor Dr. Jesse Bering
University of Otago	University of Otago
+64 3 471 6147	+64 3 471 6147
daniel.silva@postgrad.otago.ac.nz	jesse.bering@otago.ac.nz

This study has been approved by the University of Otago Human Ethics Committee Reference Number D20/152. However, if you have any concerns about the ethical conduct of the research you may contact the University of Otago Human Ethics Committee through the Human Ethics Committee Administrator (ph +643 479 8256 or email gary.witte@otago.ac.nz). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

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NEW ZEALAND

CONSENT FORM FOR PARTICIPANTS

I have read the Information Sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.
I know that:

1. My participation in the project is entirely voluntary;
2. I am free to withdraw my data from the project at any time without any disadvantage;
3. Personal identifying information will be destroyed at the conclusion of the project. However, the raw data from this project may be publicly archived so that it may be used by other researchers. All information that could identify me will be removed or changed;
4. I will receive $0.50USD for completing the task and the survey;
5. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand);
6. Every attempt will be made to preserve my anonymity;

I agree to take part in this project.

I decline to take part in this project.

....
(Signature of participant) (Date)

....
(Printed Name)

Appendix EE – Ethics approval 4: #D20/294

D20/294

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND

Academic Services
Manager, Academic Committees and Services, Mr Gary Witte

9 October 2020

Dr J Bering
Centre for Science Communication
133 Union St East

Dear Dr Bering,

I am writing to confirm for you the status of your proposal entitled "**Examining convergent and discriminant validity of the Consumption of Communication scale.**", which was originally received on September 25, 2020. The Human Ethics Committee's reference number for this proposal is **D20/294**.

The above application was Category B and had therefore been considered within the Department or School. The outcome was subsequently reviewed by the University of Otago Human Ethics Committee. The outcome of that consideration was that the proposal was approved.

Approval is for up to three years from the date of HOD approval. If this project has not been completed within three years of this date, re-approval must be requested. If the nature, consent, location, procedures or personnel of your approved application change, please advise me in writing.

Yours sincerely,

Gary Witte

Mr Gary Witte
Manager, Academic Committees and Services
Tel: 479 8256
Email: gary.witte@otago.ac.nz

Appendix FF – Information sheet and consent form 4: Consumption of science communication scale validation

I have read the Information Sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:

1. My participation in the project is entirely voluntary;
2. I am free to withdraw my data from the project at any time without any disadvantage;
3. Personal identifying information will be destroyed at the conclusion of the project. However, the raw data from this project may be publicly archived so that it may be used by other researchers. All information that could identify me will be removed or changed;
4. I will receive $1.00USD for completing the survey;
5. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand);
6. Every attempt will be made to preserve my anonymity.

Appendix GG – Results from QCA

Name	References	Elements of situation
1. Attention foci	182	
Accomplishment	9	a child learning quickly, a baby making a full sentence, a child teaching his grandfather science, completing a work project, an old person running for 24 hours, an Olympic accomplishment, overcoming fear, someone receiving an award, surviving cancer
Living organism	23	a fox, a moose, a school of squid., a sea slug that incorporates algae into its skin, a worm, aliens, animal eyes, birds of paradise, butterfly hatching, charismatic megafauna, life cycle of parasitic worm, life in a drop of water, mosquito larvae, moss, parasites, plants, sharks
Natural object	48	blackholes, British countryside, clouds in the sky, exoplanets, forest, galaxies, Grand Canyon, hurricane, mountains, general nature, Niagara Falls, panoramic view, space, sunset, supernovas, the birth of a star, the change of seasons, the night sky, the ocean, the planet, the sky, the universe, the world's largest caldera, weather effects, whale skeleton
Non-science related artefact, practice, or idea	31	a book, animation, architecture, craft in documentary clip, everything, exploration, explosion, famous painting, films, god, graveyard, Guinness World Records, indoor rainbow, magic, metaphysical ideas, a moment of realization, musical instruments, New York Skyscape, paintings, philosophy, rioting, slavery, the state of the economy, thinking about how lucky you are
Non-science related person	4	acrobats, community workers, marginalized people, strangers
Science-related artefact, practice, or idea	61	a new technology, a popular science article, a science metaphor, a science narrative, artificial intelligence, deep sea exploration, evolution, genome sequencing, nanotechnology, nature documentaries, online database, particle accelerators, realizing how nature works, robots, rocket launches, science demonstration, science installation, science picture book, science talk, scientific breakthrough, space exploration, technology, the Galileo project, the human brain, the way bodies work, the way gravity works, the way life works, the way neutrinos work, vaccines, voyager probes
Science-related person	6	doctors, science communicators, themselves
2. Social context	32	
Alone	10	
Dyad	8	with one friend, one-on-one with an expert, with a partner
Small Group	9	close family, in a small group, in a team, small group of friends, with some strangers
Large Group	5	as member of an audience, in a class, in front of a crowd
3. Setting	75	
Natural	16	a cave, Adrian's wall trail, beach, desert, forest, in nature, in the ocean, marsh, national park, park, top of a hill
Non-science-related built	42	auditorium, bar, car, classroom, graveyard, home, hospital, hotel, in front of a screen, non-science museum, school, sports track, street, theatre, visitor centre
Science related built	17	aquarium, science festival stand, natural history museum, observatory, pop up museum, science centre, science conference, science museum
4. Event	71	
Arts, culture, and entertainment	19	at an arts festival, museum visit, online surfing, reading, watching a film
Business and trade	8	careers talk, mentoring, researching, talking to patients, talking with an expert

Private	10	driving, family activity, going home, growing plants during lockdown, hanging out with friend, talking with a doctor, visiting a graveyard
Scientific and educational	22	doing astrophotography, doing scientific exploration, during a gardening workshop, during a science film hackathon, during a workshop at a science festival, school visit to science centre, science communication workshop, science conference, science show, science-related talk, visit to science museum
Sports and recreation	12	diving, going for a run, on a walk, snorkelling, during a race, vacation
5. Appraisal - Evaluation	309	
Aesthetic of merit	22	ability, diversity, importance, virtue
Aesthetic of the Burkean sublime	83	coldness, complexity, confusion, contrast, difficulty, dissonance, distance, escalation, greatness, horror, limit, power, powerlessness, rarity, ugliness, unrelatable, vastness
Aesthetic of the marvellous	102	amazing, anticipation, catchiness, coolness, disbelief, flashy, incredible, magical, novelty, rarity, surrealness, unexpectedness, uniqueness, weirdness
Aesthetic of beauty	44	beauty, caring, comforting, cuteness, diversity, familiarity, fragility, safety, silence, simplicity, smallness, stillness, subtlety, tactile
Aesthetic of the supernatural	46	connectedness, ignorance, immersion, incomprehensible, ineffability, numinous, transcendental
Other aesthetics	12	animated, funny, futuristic, identification, participation
6. Valence	16	
Positive	10	
Positive and negative	6	
7. Arousal	15	
Both exciting and calm	3	
Calm	2	
Excited	10	
8. Other emotions	113	
Stereotypically described negative emotions	7	disgust, fear, jealousy, loneliness, sadness
Stereotypically described positive emotions	106	admiration, amazement, appreciation, bewilderment, cheerfulness, contentment, delight, ecstasy, empathy, enthusiasm, fascination, gratitude, happiness, inspiration, joy, love, marvel, pride, surprise, togetherness, trust, wonder
9. Motivation	58	
to act	6	
to create	2	
to explore	2	
to learn	32	
to share	8	
to stay in the moment	3	
to transcend	1	
to work	4	
10. Actions	70	
Behaviour	21	clapping, engage with the object, freezing, grab nose, move away from object, passively watch the object, point at things, seeking behaviour, shaking hands
Communicated to others	9	communicate online, verbal communication
Expression	40	crying, holding breath, inhaling deeply, open mouth, saying 'wow', smiling, speechlessness, wide eyes

11. Bodily sensations	56	
Full body sensations	31	being lit inside, being moved, bittersweet pain, buzz, dizziness, lightness, nervousness, overwhelm, relaxation, rush, shivering, shock, smallness, something growing inside, tension
Localized sensations	11	choking, different heartbeat, heavy breathing, stomach tingling, tunnel vision
Mental sensations	14	autopilot, euphoria, focus, mindblown, out of body experience, present in the moment
12. Outcomes	106	
General outcomes	63	assign value to a person, assign value to an object, become content with not knowing, calm down, care, change in general attitudes and perception, constitute a memory, contemplate, disengage from a situation, engage with object, idea, or person, family bonding, influence short-term decision making, learn something, notice something, thwart learning, realization, recover, reinforce identity, share with others
Science-related outcomes	43	build a relationship with science, capture attention at a show or exhibition, connect science with daily lives, constitute a science-related memory, create an expectation about a technology, engage with a science communicator, influence career in science decisions, learn science, loose trust in science, make people fatigued of science hype, make science less accessible, prevent learning, reach out to scientist, impede questioning
Total	1103	